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Region 2 RAC2
Remedial Action Contract

Revised Final Feasibility Study Report

Cidra Groundwater Contamination Site

Remedial Investigation/Feasibility Study

Cidra, Puerto Rico

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CDM Smith

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Acronyms

A/E	architecture and engineering
AOC	area of concern
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
CAA	Clean Air Act
CAMU	Corrective Action Management Unit
CCC	Cidra Convention Center
CDM Smith	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CLP	Contract Laboratory Program
CMC	Cidra Metal Caskets
COPC	chemicals of potential concern
CSM	conceptual site model
CTE	central tendency exposure
CWA	Clean Water Act
DAF	dilatation attenuation factor
DCE	dichloroethene
DHC	*Dehalococcoides spp.*
DNAPL	dense non-aqueous phase liquids
DPT	direct-push technology
EAB	enhanced anaerobic bioremediation
EPA	United States Environmental Protection Agency
ERH	electrical resistance heating
ESI	expanded site inspection
EVO	emulsified vegetable oil
EZVI	emulsified zero-valent iron
GAC	granular activated carbon
GRA	general response action
gpm	gallons per minute
HHRA	Human Health Risk Assessment
HI	hazard index
ISCO	in situ chemical oxidation
ISCR	in situ chemical reduction
IDC	International Dry Cleaners
ISTR	in situ thermal remediation
ITRC	Interstate Technology and Regulatory Council
LDR	Land Disposal Restriction
MCLs	maximum contaminant levels
mg/kg	milligram per kilogram

mg/L	milligrams per liter
MMO	methane monooxygenases
MNA	monitored natural attenuation
msl	mean sea level
MTR	minimum technology requirements
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Corporation
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OU	Operable United
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
ppb	parts per billion
POTW	publicly-owned treatment works
PPE	personal protective equipment
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRB	permeable reactive barrier
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PRDOH	Puerto Rico Department of Health
PREQB	Puerto Rico Environmental Quality Board
PRG	preliminary remediation goal
PRWQS	Puerto Rico Water Quality Standards
RAC	Remedial Action Contract
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RGA	Richard Grubb & Associates
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROD	Record of Decision
RSL	Regional Screening Levels
SLERA	Screening Level Ecological Risk Assessment
SMW	saprolite monitoring well
SQL	sample quantitation limit
SSL	soil screening level
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TBC	to be considered
TCA	tetrachloroethane
TCE	trichloroethene
TCH	thermal conductive heating

TCLP	Toxicity Characteristic Leaching Procedure
TGP	Tech Group de Puerto Rico, Inc.
T/M/V	toxicity/mobility/volume
UIC	Underground Injection Control
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
UTS	Universal Treatment Standards
UV	ultraviolet
VOC	volatile organic compounds
WA	Work Assignment
ZEN	Zenith Laboratories Caribe, Inc.
ZVI	zero-valent iron

Executive Summary

Introduction

CDM Federal Programs Corporation (CDM Smith) received Work Assignment (WA) 168-RICO-02WE for the Cidra Groundwater Contamination Site (the site or Cidra site) located in Cidra, Puerto Rico, under the Response Action Contract, Contract No. 68-W-98-210 for the United States Environmental Protection Agency (EPA), Region 2. This WA was continued under the EPA Region 2 Remedial Action Contract (RAC), Contract No. EP-W-09-002, as WA 004-RICO-02WE. The objective of this WA is to perform a Remedial Investigation/Feasibility Study (RI/FS), a human health risk assessment (HHRA), and a screening level ecological risk assessment (SLERA) for the site.

Site Location and Description

The municipality of Cidra is located in the central-eastern section of Puerto Rico in the northern foothills of the Cordillera Central Mountain Range. The Cidra site consists of a plume of groundwater contaminated with chlorinated volatile organic compounds (VOCs) in an industrial area of Cidra. Topography generally slopes south from the commercial district to a narrow southwest-trending valley and unnamed stream. The unnamed stream drains the area and flows into the Rio Arroyata southwest of the site; the Rio Arroyata forms the topographic low.

The site consists of two contaminated soil source zones, namely former International Dry Cleaners (IDC) facility and Ramallo/Cidra Convention Center (Ramallo or Ramallo/CCC), a plume of groundwater contaminated with chlorinated volatile organic compounds (VOCs), and four closed Puerto Rico Aqueduct and Sewer Authority (PRASA) public supply wells. The Puerto Rico Department of Health (PRDOH) closed the four PRASA public supply wells from 1996 to 2000, due to tetrachloroethene (PCE) contamination. There are 15 active drinking water wells located within 4 miles of the site, serving over 8,000 people. The closed and active wells range in depth from 110 to 705 feet below the ground surface (bgs), and are completed in the underlying Pre-Robles volcanic bedrock aquifer.

Physical Setting of the Study Area

Surface Drainage

Cidra is situated at the surface water drainage divide between the Rio de la Plata and Rio de Bayamon drainage basins. Several drainage valleys discharge either southwest into the Rio de la Plata or northeast into the Rio de Bayamon drainage basins. The majority of surface water drainage across the site flows south and west toward an unnamed stream and the Rio Arroyata, a tributary of Rio de la Plata. Areas to the north and east of the site drain into Lago de Cidra, located 0.5 mile east of the site, which is part of the Rio de Bayamon drainage basin. A surface water intake, located approximately 2.2 miles downstream of Lago de Cidra, serves approximately 20,000 people. The site is located outside of the 500-year flood boundary.

Soil Characteristics

The majority of site soils are classified by the U. S. Department of Agriculture Natural Resources Conservation Service (NRCS) as non-irrigated urban land mixed with approximately 25% Vega Alta Complex (Uv). The Vega Alta soils are fine-textured, iron-rich coastal plain sediments that are located on the toeslopes of terraces. They are typically well-drained soils with a high available water capacity. In undisturbed sequences, the top eight inches of these soils are a clayey loam, overlying clay.

The DJ Manufacturing, IVAX, and Pepsi, and the majority of the Shellfoam, Ramallo/Cidra Convention Center, ENCO properties are situated on soils classified by NRCS as Daguey Clay (DaD), which is well-drained and has a high available water capacity. The top six feet are described as being predominantly clay, overlying a clayey loam.

The Juncos Clay, which is mapped by the NRCS in the southern portion of Cidra, has a high shrink-swell capacity, is moderately well drained, but has a low available water capacity and low permeability. It is comprised of approximately four feet of clay overlying competent bedrock, and tends to occur on hillslopes (toeslopes).

Geology and Hydrogeology

Cidra is located within the Central Volcanic Province of Puerto Rico, which is bound to the north by the left-lateral strike-slip Cerro Mula fault and contains numerous major strike-slip faults that parallel it. The following three strata, from top to bottom, were encountered at the site.

- Quaternary Silt and Clay (terrace deposits) - The depth to the bottom of the silty clay unit varies from 55 to 105 feet bgs. This layer is thicker in the northern area near IDC (approximately 100 feet) than in the southern area by Ramallo/CCC (approximately 70 feet). The low permeability of this unit hinders groundwater infiltration through the overburden to the groundwater table. However, fractures and lineations observed in the silty clays may provide secondary permeability that would enhance groundwater infiltration to the underlying units.

- Saprolite (decomposed bedrock) - The saprolite, which occurs below the silt and clay, is the result of chemical weathering of the underlying volcanic rocks. The material is a hard, wet, brown to light brown, sandy to silty clay with abundant dark brown to brown, angular to very angular, mafic rock fragments with fine-grained texture. The saprolite crumbles easily under light pressure. Where present, the unit ranges in thickness from 45 to 60 feet. The contact between the saprolite and the underlying bedrock ranged from 109 to 156 feet bgs. The saprolite, which is semi-confined by the overlying silty clays, is a major water-bearing unit in the area. Groundwater flows downward and laterally to the west/southwest and enters fractures at the top of the volcanic bedrock.

  Cretaceous Pre-Robles Volcanic Bedrock (Formation J) - The bedrock in the region is a massive volcanic breccia that is estimated to be a maximum of approximately 2,700 meters thick. The porosity of the bedrock is only two to three percent, but joints and fractures can enhance groundwater flow considerably. Bedding planes in the bedrock act as individual aquifers, separated by aquitards consisting of relatively low permeability bedrock, where less fracturing is present. Across the majority of the site, groundwater flow is to the west/southwest toward the Rio Arroyata. However, in the IVAX area, which is closer to the Arroyata Fault, bedding planes and fractures strike northwest/southeast, indicating a groundwater divide somewhere on the IVAX facility and the groundwater flows to the southeast. Groundwater at the site is classified as suitable for drinking water use (SG).

Surface Water-Groundwater Interaction

Groundwater in the saprolite zone is hydraulically connected to the Rio Arroyata. During the RI, potentiometric water levels indicated that groundwater discharges to the river through seeps along the river bank or directly to the river. No seeps were observed during the surface water/sediment sampling event; however, since water levels were high due to rain events, and any seeps may have been below the water level in the stream. Several groundwater seeps were observed along the banks of the Rio Arroyata downstream.

Nature and Extent of Contamination

Summary of Soil Contamination

- Site-related VOCs were detected in soil samples at IDC, Ramallo/CCC, CCL Label, ENCO, DJ Manufacturing Don Quixote, and ESSO. The majority of exceedances and the highest levels were found in soils at IDC and Ramallo/CCC.

- No VOCs were detected at the Coffee Shop or Ramoncito. A few VOCs were detected at IVAX, Pepsi, and Shellfoam, but at levels below screening criteria; none were site-related VOCs.

- The main source of contamination in the southern area of the site is at Ramallo/CCC with the highest levels of site-related contaminants found in shallow soils in the northeastern portion of the facility in RMSB-18 (PCE at 3,300,000 micrograms per kilogram (µg/kg) and trichloroethene (TCE) at 2700J µg/kg (0-2 feet bgs)).

- The highest levels of site-related contaminants in the northern drainage area were found at IDC (PCE at 1,700,000 µg/kg (4-8 feet bgs) and TCE at 39,000 µg/kg (4-6 feet bgs); contaminant levels generally decreased with depth.

Summary of Soil Vapor Contamination

- PCE and TCE were present in subslab soil gas at concentrations several orders of magnitude higher than their respective screening levels at both the IDC and Ramallo/CCC source areas. PCE was also detected in subslab soil vapor samples in ENCO, CCL Label, Former 579 Store, and Praxedes Public Housing, indicating that PCE vapor has migrated in the subsurface to buildings closely proximal to the source areas.

- There are no indoor air screening level exceedances for site-related contaminants at any locations. However, PCE, TCE, and cis-1,2-DCE vapors have migrated from the subsurface into indoor air at the IDC, Former 579 Store, Ramallo/CCC, and Praxedes Public Housing properties. TCE was also detected in ambient air samples, suggesting that non-site related sources may have contributed to TCE found in indoor air.

- Several non-site-related VOCs were detected at levels above their respective screening levels in indoor air. The presence, concentrations, and distribution of VOCs in subsurface, within buildings, and ambient air indicate that these VOC exceedances were mostly attributable to indoor sources and background levels rather than vapor intrusion.

Summary of Groundwater Contamination

- No exceedances were found in any of the wells downgradient of IDC in the northern area. Low levels of site-related contaminants below the screening criteria were observed.

- The groundwater contamination in the southern area originates at the Ramallo/CCC facility and extends southwest toward the Rio Arroyata.

- Overall, the highest levels of site-related contaminants in groundwater were detected in the saprolite wells located at and downgradient of Ramallo/CCC: SMW-10 (62-72 feet bgs) had a PCE concentration of 1,700 micrograms (µg/L) and a TCE concentration of 31 µg/L, and SMW-1(48-58 feet bgs) had a PCE concentration of 680 µg/L and a TCE concentration of 14 µg/L.

- In the bedrock, MPW-5 had the highest levels and the most PCE exceedances in the five deepest ports, with a maximum of 120 µg/L in port 4 (260-274 feet bgs). TCE follows a similar pattern with the highest concentration (5.3 µg/L) occurring at port 7 (302-324 feet bgs).

Summary of SW/Sediment Contamination

- Groundwater in the saprolite zone is hydraulically connected to the Rio Arroyata and the contaminant plume extends to the Rio Arroyata, although it is unknown whether it extends under and southwest of the river.

- Contaminant levels in surface water were lower than in the nearby saprolite wells.

Conceptual Site Model

Ramallo/CCC Area

- Contaminants were likely discharged directly to the ground at the Ramallo/CCC source area, and migrated downward with precipitation through lineations in the overburden, drawing dissolved contamination deeper into the soils. Along these flow paths, contamination diffused into the surrounding low permeability clay matrix. Contamination then migrated into the groundwater aquifer in the underlying saprolite.

- PCE contamination moves southwest with groundwater flow in the saprolite, as evidenced by PCE levels in SMW-10 and SMW-1 1,700 µg/L and 680 µg/L, respectively. The saprolite layer contains the highest levels of PCE in groundwater at the site, and recharges the underlying bedrock aquifer. Figure 1-15 shows the general orientation of the PCE contaminant plume in the saprolite zone, which extends horizontally to the Rio Arroyata.

- Contamination enters bedrock bedding planes and fractures just upgradient of MPW-1, as evidenced by PCE in shallow bedrock in this well. Contamination spreads along strike (primarily to the south), and downdip (to the west). MPW-5 and Cidra 8 are along this contaminant migration pathway, and exhibit contamination at deeper depths.

International Dry Cleaner Area

- Contaminants were likely discharged directly to the ground at the IDC. The majority of the surface in the vicinity of the IDC is overlain by buildings and roads, which prohibit the majority of precipitation from infiltrating into the overburden. As a result, the bulk of precipitation drains via overland flow toward the northern drainage area. The remainder migrates downward through the overburden in unpaved areas and through areas where contaminants were discharged, resulting in the accumulation of dissolved contamination in the infiltrating water. Infiltration into the soil is possibly enhanced by lineations. Along the infiltration pathways, contamination likely diffuses into the surrounding low permeability clay matrix. Contaminant transport to the depth of groundwater through this unit may be hindered in this area, as compared to Ramallo, due to greater overburden thickness (approximately 30 feet thicker) and gradation to finer-grained soils with depth.

- Low-levels of contamination could eventually reach the saprolite zone and migrate to the top of bedrock, as indicated by the low-level detections of site-related VOCs in monitoring wells downdgradient of IDC.
- Once in bedding planes and fractures, contamination spreads along strike and moves down dip. The overall flow direction is to the southwest toward MPW-2, MPW-3, MPW-4, and Cidra 3, resulting in the low levels of PCE in these wells.

Surface Water /Sediment

- Groundwater contamination migrating in the saprolite zone from Ramallo/CCC discharges to the Rio Arroyata via seeps. Contaminant levels in the surface water, which are below screening criteria, are highest in areas adjacent to nearby saprolite wells, and generally decrease downstream.

Risk Assessments

Human Health Risk Assessment

HHRA exposure pathways are defined based on potential source areas, release mechanisms, and current and potential future uses of the properties. Potential receptors evaluated in the risk assessment are summarized below.

- Current Land-Use Scenarios
  - Workers, Trespassers, and Residents at IDC
  - Workers at CCL Label, Ramallo/CCC, ENCO, Shellfoam, DJ Manufacturing, IVAX, and Pepsi
  - Recreational Users at Rio Arroyata
- Future Land-Use Scenarios
  - Workers, Trespassers, Residents, and Construction Workers at All Sites
  - Recreational Users at Rio Arroyata

The total hazard indices (HIs) for all current and future receptors, except current receptors at Exposure Area 2 and future trespassers at Exposure Area 1 under the reasonable maximum exposure (RME) scenario, are above EPA's threshold of unity (1). The current and future workers at Exposure Areas 3 and 4, the current and future recreational users and the future construction workers have noncancer HIs exceeding EPA's threshold under the RME scenario for the kidney and respiratory system due to exposure to vanadium in soil. Under the central tendency exposure (CTE) scenario, the total HIs are at or below EPA's threshold. The future residents have noncancer HIs exceeding EPA's threshold under the RME scenario for the cardiovascular system, central nervous system (CNS), developmental, heart, immune system, kidney, liver, lung, nervous system, respiratory system, skin, and thyroid due to exposure to PCE, 1,1,2-trichloroethane, TCE, arsenic, cobalt, and vanadium. Under the CTE scenario, the total HIs are still above EPA's threshold. The potential health hazards to the cardiovascular system, CNS, development, kidney, liver, lung, nervous system, respiratory system, and skin are due to exposure to arsenic, PCE, and vanadium in soil and groundwater. Risks associated with arsenic and vanadium are most likely overestimated.

Future residents may potentially be exposed to volatile contaminants of potential concern (COPCs) via inhalation of vapor emanating from groundwater into enclosed structures via vapor intrusion and into ambient air via vaporization.

Screening Level Ecological Risk Assessment

Results of the SLERA indicated potential risk from exposure to several metals. In general, concentrations of these metals in background samples were either higher than, or similar to the maximum concentrations of metals detected in site sediment and surface water. The concentrations of metals detected are most likely reflective of natural conditions, or non site-related sources.

The site-related chemical PCE was detected in one sediment sample, and cis-1,2-DCE, PCE, and TCE were detected in surface water samples taken from the Rio Arroyata. However, all concentrations were orders of magnitude below their respective ESLs. Therefore, the site poses no site-related risk to ecological receptors.

Remedial Action Objectives

The HHRA indicates that the direct contact risks from exposure to site-related contaminants at IDC are within EPA's acceptable risk range. At Ramallo, PCE would pose direct contact risks to future workers and residents. Remedial action alternatives have been developed to focus on reducing the impact to groundwater quality and protection of human health.

The RAOs for soil are to:

- Prevent/minimize contaminated soil at the site from serving as a source of groundwater contamination by isolating or remediating soils with contaminant concentrations exceeding groundwater protection preliminary remediation goals (PRGs)
- Prevent/minimize human exposure to soils with contaminant concentrations in excess of the PRGs.

The RAO for soil vapor is:

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at the site.

The RAOs for groundwater are to:

- Prevent human exposure to contaminants above levels that are protective of drinking water
- Restore the groundwater to drinking water quality to the extent practicable

Soil Preliminary Remediation Goals
PRGs for soil were derived based on protection of groundwater for the site. Although PRGs are the ultimate concentration goals for site cleanup, they may not be achievable during the remedial action due to limitations of currently available treatment technologies and the deep contamination in the silty clay. Therefore, the treatment technologies focus on soil hotspots (localized areas of soil contamination that are significantly higher than seen throughout the rest of the site) where historic dumping is suspected.

Screening Criteria for Vapor Intrusion
A Federal chemical-specific ARAR was identified for vapor intrusion. The suitable sub-slab contaminant screening criteria and indoor air concentrations requiring mitigation were developed using EPA's Vapor Intrusion Screening Levels (VISLs). No Commonwealth ARARs were identified for vapor intrusion.

Groundwater Preliminary Remediation Goals
Groundwater at the site is classified as suitable for drinking water use (SG). Therefore, federal drinking water standards are relevant and appropriate requirements, and were used to derive groundwater PRGs. Puerto Rico Water Quality Standard (PRWQS) Regulations (a TBC), were also considered if any remedial alternatives under consideration included discharges to any waters of Puerto Rico.

Deed restrictions will be in place to prevent well installation and access to the groundwater which will protect people from exposure to contaminant concentrations over permissible limits. Over time, it is expected that the aquifer will eventually achieve PRGs through remedial actions and naturally occurring mechanisms such as dilution and dispersion.

Soil Remedial Action Alternatives
Various remediation methods or technologies were screened against Site-specific conditions using three criteria: effectiveness, implementability, and relative cost. Representative process options were selected from the retained remedial technologies to develop remedial alternatives. However, other process options may still be applicable and should be considered during the remedial design stage of the project. Remedial alternatives were developed separately for the two different source areas.

Several common elements were assumed to be part of each remedial alternative including the possibility of installing vapor mitigation systems, pre-design investigations, institutional controls, and five-year site reviews.

Soil Alternatives for IDC
- **Alternative IDC-S1: No Action** - The No Action alternative is required by the National Contingency Plan (NCP) to be carried through the screening process. The No Action alternative serves as a baseline for comparison with other site remedial alternatives.

- **Alternative IDC-S2: Containment** – Contaminants would be left in place, and a cap would be installed on the unpaved areas; the existing building would also serve to cap underlying contaminated soils. The cap would reduce rainwater infiltration, thus slowing any further infiltration-induced migration of contaminants in the vadose zone. Although capping would not meet soil PRGs across the majority of the site (since soil contamination would be left in place), this alternative may be sufficient to meet the RAOs because there is little groundwater contamination at IDC, and soil contaminant concentrations would slowly biodegrade and volatilize over time. Vapor mitigation systems may be installed depending on vapor sampling results. Institutional controls and regular monitoring and maintenance of the cap would be required.

- **Alternative IDC-S3: Enhanced Soil Vapor Extraction and Containment** - The principal threat waste would be targeted with soil vapor extraction, and capping would be implemented as described above for Alternative IDC-S2. For cost estimating purposes, it is assumed that the hotspot in the alleyway would be targeted. The actual extent of the principal threat wastes to be remediated would be determined during a pre-design investigation. Vapor mitigation systems may be installed depending on vapor sampling results.

Soil Alternatives for Ramallo

- **Alternative R-S1: No Action** - The No Action alternative is required by the NCP to be carried through the screening process. The No Action alternative serves as a baseline for comparison with other site remedial alternatives.

- **Alternative R-S2: Containment** - In the same manner as described for the IDC capping alternative above, a cap would be installed at Ramallo on the unpaved areas where rainwater may infiltrate into contaminated soils, and the existing building would function as a cap of underlying contaminated soils. Repair would be made to existing concrete cover as necessary. Vapor mitigation systems may be installed depending on vapor sampling results.

- **Alternative R-S3: Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment -** For this alternative, soil vapor extraction would be enhanced by thermal heating of the treatment zone. A hollow stem auger would be used inside and outside the building to advance combined SVE wells and heating electrodes to the bottom of the treatment zone on approximately 20 foot centers. The electrical equipment, compressor for the system and the vapor and condensate treatment system would be located on the Ramallo property. Surface soil contamination would be excavated and disposed off-site in a Resource Conservation and Recovery Act (RCRA) Subtitle C landfill. A cap would then be installed across the extent of the remediation target zone to minimize infiltration of rainwater into the contaminated soil. The cap would need to be inspected and maintained indefinitely. Vapor mitigation systems may be installed depending on vapor sampling results.

- **Alternative R-S4: In Situ Chemical Treatment and Containment** - In situ chemical treatment would be used to remediate the high-concentration contaminants in soils, and the remainder of the remediation target zone would be capped. PCE degradation byproducts indicate that the clay is moist enough to sustain biological growth, the redox conditions are amenable to reductive dechlorination, and the existing microbes are capable of destroying the contaminants at the site. A combined in situ chemical reduction (ISCR)/bioremediation amendment would be introduced in the deeper soils to provide a carbon source for further growth of the dehalogenating microbes. Amendment delivery mechanisms would be evaluated and selected during the design phase. In the surface soils, an amendment would be introduced with mechanical mixing. Vapor mitigation systems may be installed depending on vapor sampling results.

Groundwater Remedial Action Alternatives

The remedial alternatives to address groundwater contamination at the site are summarized below. Several common elements assumed to be part of each remedial alternative including pre-design investigations, long-term monitoring, institutional controls, and five-year site reviews.

- **Alternative GW1: No Action** - The No Action alternative is required by the NCP to be carried through the screening process. The No Action alternative serves as a baseline for comparison with other site remedial alternatives.

- **Alternative GW2: Groundwater Extraction, Treatment, and Long-term Monitoring** – Groundwater extraction, treatment, and disposal would be implemented for the entire groundwater plume in both the saprolite and the bedrock aquifers; the plume is defined as groundwater with contaminants above PRGs. Groundwater extraction would serve to extract contamination from the aquifer, and also create a hydraulic barrier to further contaminant migration into the bedrock and downgradient. It is assumed that the water effluent from the air stripper would be polished with activated carbon to meet Puerto Rico standards and then discharged to surface water. Extraction and treatment would continue until the aquifer has been restored to the extent practicable.

- **Alternative GW3: Focused Groundwater Extraction, Treatment, and Long-term Monitoring** - Under this alternative, groundwater extraction, treatment, and disposal would be implemented as described for Alternative GW2, with the exception that it would target a focused area which would be determined during the remedial design phase based upon modeling to optimize extraction well location to prevent extraction of clean water. For areas outside of the extraction and treatment zone, long-term monitoring of the saprolite and bedrock aquifers would be performed to assess degradation of contaminants.

- **Alternative GW4: In situ Treatment and Long-term Monitoring** – In situ chemical or biological treatment would be implemented for the saprolite aquifer within a focused isocontour to be determined after a pre-design investigation. During the remedial design phase, numerical groundwater modeling would be performed to determine if a permeable reactive barrier (PRB) would be necessary to remediate the downgradient portion of the PCE plume. The exact location would be determined after a treatability and/or pilot study to determine the technical limitations of the PRB. RAOs would eventually be met inside the saprolite plume due to advection moving the contamination through the PRB. It is assumed that the PRB would need to be periodically refreshed or reinstalled when reactivity fades. In situ treatment would continue until the aquifer has been restored to the extent practicable. For areas outside of the in situ treatment zone, long-term monitoring of the saprolite and bedrock aquifers would be performed to assess degradation of contaminants.

Comparative Analysis of IDC Soil Remedial Action Alternatives

Overall Protection of Human Health and the Environment

Since human health risks and ecological risks associated with site-related contaminants from direct contact are within EPA's acceptable range, all alternatives would be protective of human health and environment. However, the No Action alternative would not meet RAOs since the contamination in the soil can leach into groundwater and act as a source of contamination for groundwater. Alternatives 2 and 3 would minimize infiltration of rainwater, thereby hindering contaminant migration in the vadose zone.

Compliance with ARARs

There are no Federal or Puerto Rico chemical-specific ARARs for soil. All alternatives would comply with location-specific and action-specific ARARs.

Long Term Effectiveness and Permanence

The No Action alternative is not effective or permanent over the long-term. For Alternative IDC-S2, the cap is not considered a permanent remedy because it does not reduce the toxicity/mobility/volume (T/M/V) of contamination. A cap does have the potential to effectively meet RAOs over the long-term if the cap is well-maintained indefinitely. For Alternative IDC-S3 with SVE, technical limitations could prevent all the contamination from being removed in the clayey soil. In the remainder of the targeted treatment zone where SVE is not implemented, a well-maintained cap and institutional controls would be critical to the ability to meet RAOs over the long-term.

Reduction of Toxicity/Mobility/Volume Through Treatment

The No Action alternative would not reduce contaminant T/M/V since no remedial action would be conducted. The capping alternative would not reduce toxicity or volume, but would be designed to reduce mobility by minimizing infiltration of rainwater into the contaminated soil. If it is effective in the clayey soil matrix, SVE would reduce T/M/V through treatment. The extent and effectiveness of T/M/V reduction would need to be verified with monitoring.

Short Term Effectiveness

There would be no short-term impact to the community and environment for the No Action alternative. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction and operation. Air monitoring, engineering controls, and appropriate worker personal protection equipment (PPE) would be used to protect the community and workers for these alternatives.

Implementability

The No Action alternative would be the easiest to implement, both technically and administratively, as no additional work would be performed at the site. Experienced vendors would be readily available to implement capping and SVE. An implementability concern to highlight for capping is that it would require maintenance and inspection indefinitely. For SVE, the major implementability limitation is access for drill rigs to the treatment zone since, currently, the alleyway is too narrow to fit a rig. The building and alleyway would need to be modified to permit access. A permit would be required to discharge vapor from the SVE system to the atmosphere.

Cost

IDC-S3 has the highest capital cost and present worth, followed by IDC-S2.

IDC Soil Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring costs	Total Present Worth
IDC-S1	$0	$0	$0
IDC-S2	$ 159,000	$ 46,000	$ 205,000
IDC-S3	$ 1,239,000	$ 556,000	$ 1,795,000

Comparative Analysis of Ramallo Soil Remedial Action Alternatives

Overall Protection of Human Health and the Environment

Alternative R-S1, No Action, would not meet the RAOs and would not be protective of human health and the environment since no action would be taken. Contamination would remain in the soil, while no mechanisms would be implemented to prevent direct contact with the contaminated soils, migration of contaminants to the groundwater, or to reduce the T/M/V of contamination except through natural attenuation processes, which would not be monitored to assess the effectiveness or predict the duration of this alternative.

The protectiveness of Alternative R-S2, Containment, relies on continuing maintenance of a cap indefinitely. A well-maintained cap would be a barrier for direct contact and rainwater infiltration. While the cap can be expected to slow the flux of contamination from soil and into the underlying groundwater, it may not stop the flux completely; consequently, the underlying groundwater may continue to be impacted. Only monitoring over time could answer this question.

Alternative R-S3 is the most likely to be protective over time because this alternative actively removes contaminant mass from the subsurface. SVE and thermal treatment are expected to remove most of the contaminant mass from the treatment zone (over 90%).

Alternative R-S4 would provide treatment to the hot spot, but the effectiveness is uncertain without a pilot study. Nonetheless, given the technical limitations of these in situ treatment technologies in clayey soil, a significant portion of the contamination would not be removed and it would be necessary to rely on a cap over the long-term to ensure protectiveness. As mentioned above, reliance on long-term maintenance means capping can only be conditionally protective.

The long-term soil vapor monitoring program in Alternatives R-S2 through R-S4 would monitor for vapor intrusion to ensure human health is protected.

Alternatives R-S2, R-S3, and R-S4 would achieve the RAOs.

Compliance with ARARs

There are no Federal or Puerto Rico chemical-specific ARARs for soil. All the alternatives except No Action would comply with location-specific and action-specific ARARs. Location- and action-specific ARARs do not apply to the No Action since no work would be implemented.

Long Term Effectiveness and Permanence

Under the No Action alternative, contamination would continue to flux from the soil into groundwater and be present at unpaved ground surface where it could impact biota and humans. No Action would not be effective or permanent over the long-term.

For the capping alternative, R-S2, the cap is not considered a permanent remedy because it does not reduce the T/M/V of contamination. A cap does have the potential to effectively meet RAOs over the long-term if the cap is well-maintained indefinitely. The active remedial alternatives, R-S3 and R-S4, are the most likely to be permanent and effective over the long-term because they remove or destroy contamination in the subsurface, thus decreasing T/M/V. Thermal remediation is expected to heat the entire volume of the treatment zone, and thus be the most effective alternative for removing diffused mass. Amendments introduced with environmental fracturing under R-S4 would diffuse into the clay to attack the existing diffused contaminants; however, introduction via discrete fractures cannot be expected to uniformly distribute amendment throughout the treatment zone, and there would likely be some gaps in treatment. As a result, not all of the contaminant mass would be removed from the clayey soil. Alternatives R-S2 through R-S4 would provide vapor intrusion mitigation as necessary. A well-maintained cap and institutional controls for Alternatives R-S2, R-S3, and R-S4 would be critical to the ability to meet RAOs over the long-term.

Reduction of Toxicity/Mobility/Volume Through Treatment

The No Action alternative would not reduce contaminant T/M/V since no remedial action would be conducted.

The capping alternative would not reduce toxicity or volume, but would be designed to reduce mobility by minimizing infiltration of rainwater into the contaminated soil. The active remedies, R-S3 and R-S4, would reduce T/M/V through treatment. SVE would remove the contamination from the subsurface, and chemical treatment would destroy the contamination in situ. The extent and effectiveness of T/M/V reduction would need to be verified with monitoring for both R-S3 and R-S4.

Short Term Effectiveness

With respect to the No Action alternative, there would be no short-term impact to the community and environment as no remedial action would occur. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction, operation, and/or injection activities. Alternative R-S3 would have the highest impact since operations would last the longest, followed by R-S4, then R-S2. Air monitoring, engineering controls, and appropriate worker PPE would be used to protect the community and workers for Alternatives R-S2 through R-S4.

Implementability

The No Action alternative would be easiest both technically and administratively to implement as no additional work would be performed at the site. Alternatives R-S2, R-S3, and R-S4 would be constructible and operable since services, materials, and experienced vendors would be readily available. Maintenance and inspection would be needed indefinitely for the capping alternative; it is difficult to predict if these activities would be performed as regularly as needed in the distant future. The in situ treatment alternative would require environmental fracturing and SVE would require thermal remediation. These are specialty environmental services and are not widely available. Lastly, R-S3 contains an excavation and disposal component. Since no landfills in Puerto Rico accept hazardous waste, difficulty could arise in the transport of excavated hazardous waste to a permitted landfill, likely somewhere in the US. A permit would also be required to emplace amendment into the subsurface and/or to discharge vapor from an SVE and thermal treatment system to the atmosphere.

Cost

Alternative R-S3 has the highest capital cost and present worth, followed by Alternative R-S4.

Ramallo Soil Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring Costs	Total Present Worth
R-S1	$0	$0	$0
R-S2	$ 299,000	$ 70,000	$ 369,000
R-S3	$ 3,664,000	$ 70,000	$ 3,734,000
R-S4	$ 1,785,000	$ 70,000	$ 1,855,000

Comparative Analysis of Groundwater Remedial Action Alternatives

Overall Protection of Human Health and the Environment

Alternative GW1, No Action, would not meet the RAOs and would not be protective of human health and the environment. Alternatives GW2, GW3, and GW4 would be effective when combined with institutional controls to prevent future human exposure to groundwater contamination. These alternatives also provide protection over time because they employ active remediation to reduce the T/M/V of contamination. These alternatives would achieve the RAO.

Compliance with ARARs

All the alternatives, except No Action, are anticipated to satisfy the chemical-specific ARARs by achieving the PRGs in the future and would comply with location-specific and action-specific ARARs.

Long Term Effectiveness and Permanence

Alternative GW-1, No Action, would not have long-term effectiveness since no action would be implemented. Alternatives GW2, GW3, and GW4 would be effective since they combine treatment, long-term monitoring and institutional controls. Alternatives GW2 and GW3 would provide additional protection as the contaminants would be removed and treated ex situ while GW4 would employ in situ treatment to destroy the contaminants. Given the hydrogeological complexity of the bedrock, it would be difficult to effectively delineate the contamination and correctly place the extraction or injection points under Alternative GW4. The effectiveness of these alternatives would be assessed through routine groundwater monitoring and five-year reviews. Alternatives GW2 and GW3 would be equally effective, followed by Alternative GW4.

Reduction of Toxicity/Mobility/Volume Through Treatment

The No Action alternative would not reduce contaminant T/M/V. Alternatives GW2, GW3, and GW4 would reduce T/M/V through treatment. It is expected Alternatives GW2 and GW3 would have higher T/M/V reduction than Alternative GW4.

Short Term Effectiveness

There would be no short-term impact to the community, environment, and the workers under the No Action Alternative. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction, operation, extraction and/or injection activities. Air monitoring, engineering controls, and appropriate worker PPE would be used to protect the community and workers for Alternatives GW2, GW3, and GW4. Alternative GW4 would have the highest degree of impact, followed by Alternatives GW 2 and GW3.

Implementability

The No Action alternative would be easiest both technically and administratively to implement as no additional work would be performed at the site. Alternatives GW2, GW3, and GW4 would be constructible and operable, since services, materials, and experienced vendors would be readily available. Land use and discharge permits can be easily obtained. Alternatives GW2 and GW3 would require space for the treatment plant and the interconnecting piping between the extraction wells and the treatment plant. Alternative GW4 would require access to a large area for injection treatment. Access and space limitation could prevent the implementation of Alternative GW4.

Cost

Alternative GW2 has the highest present worth, followed by Alternative GW3. Alternative GW4 has the highest capital cost.

Groundwater Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring costs	Total Present Worth
GW1	$0	$0	$0
GW2	$ 3,032,000	$ 6,389,000	$ 9,421,000
GW3	$ 2,715,000	$ 6,166,000	$ 8,881,000
GW4	$ 4,828,000	$ 2,547,000	$ 7,375,000

Section 1

Introduction

CDM Federal Programs Corporation (CDM Smith) received Work Assignment (WA) 168-RICO-02WE for the Cidra Groundwater Contamination Site (the site) located in Cidra, Puerto Rico, under the Response Action Contract, Contract No. 68-W-98-210 for the United States Environmental Protection Agency (EPA), Region 2. This WA was continued under the EPA Region 2 Remedial Action Contract (RAC), Contract No. EP-W-09-002, as WA 004-RICO-02WE. The objective of this WA is to perform a Remedial Investigation/Feasibility Study (RI/FS), a human health risk assessment (HHRA), and a screening level ecological risk assessment (SLERA) for the site.

This Final Feasibility Study (FS) was prepared in accordance with Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (EPA 1988) and the CDM Smith Final Work Plan Volume I (CDM Smith 2009).

1.1 Purpose and Organization of the Report

The purpose of the Final FS is to identify, develop, screen, and evaluate a range of remedial alternatives for the contaminated media and provide a basis for the FS Report to be developed. The FS report will provide the regulatory agencies with data sufficient to select a feasible and cost-effective remedial alternative that protects human health and the environment from potential risks at the site.

This Final FS is comprised of four sections as described below.

- **Section 1 - Introduction** provides a summary of site background information including the site description, site history, physical characteristics of the site, remedial investigation (RI) sampling activities, nature and extent of contamination, contaminant fate and transport, and Conceptual Site Model (CSM). The HHRA and the SLERA have been submitted as separate documents.

- **Section 2 - Development of Remedial Action Objectives and Screening of Technologies** develops a list of remedial action objectives (RAOs) by considering the characteristics of contaminants, the risk assessments, and compliance with site-specific applicable or relevant and appropriate requirements (ARARs); documents the quantity of contaminated media; identifies preliminary remediation goals (PRGs) and general response actions (GRAs) that could potentially achieve the PRGs; and identifies and screens remedial technologies and process options.

- **Section 3 - Development of Remedial Action Alternatives** presents the remedial alternatives developed by combining the feasible technologies and process options.

- **Section 4 – Detailed Analysis of Remedial Action Alternatives** provides preliminary design assumptions regarding the alternatives that were retained. This section also provides a detailed analysis of each alternative with respect to seven criteria and an overall comparative analysis conducted to compare and contrast the remedial alternatives.

- **Section 5** - **References** provides a list of references used to prepare the FS.

1.2 Site Location and Description

The Cidra Groundwater Contamination Site is location in the municipality of Cidra in the central-eastern section of Puerto Rico in the northern foothills of the Cordillera Central Mountain Range. The six-acre Superfund site consists of portions of the commercial district of the Cidra municipality and includes the Cidra Industrial Park to the southeast (Figure 1-1).

The Cidra Industrial Park, which is slightly south of the commercial district, is approximately 1,345 feet above mean sea level (msl). Between and slightly west of these two areas is the Cidra Municipal Cemetery. Topography generally slopes south from the commercial district to a narrow southwest-trending valley and unnamed stream. In the vicinity of the industrial park, topography slopes southwest toward the Rio Arroyata. The unnamed stream drains the area surrounding the Cidra Municipal Cemetery, and flows into the Rio Arroyata southwest of the site; at this point, the Rio Arroyata forms the topographic low at approximately 1,310 feet above msl.

The site consists of two contaminated soil source zones, a plume of groundwater contaminated with chlorinated volatile organic compounds (VOCs) in an industrial area of Cidra, and four closed Puerto Rico Aqueduct and Sewer Authority (PRASA) public supply wells. Figure 1-2 is a site map. The aquifer of concern at Cidra is the Pre-Robles volcanic bedrock that underlies the area and includes the saprolite. The closed and active wells are completed in this aquifer at total depths ranging from 110 to 705 feet below the ground surface (bgs). In total, there are 15 active drinking water wells located within 4 miles of the site, serving a total population of over 8,000 people (EPA 2003a).

1.3 Site History

The Puerto Rico Department of Health (PRDOH) ordered the following four PRASA public supply wells in Cidra to be closed due to tetrachloroethene (PCE) contamination; 1,1-dichloroethene (1,1-DCE) and trichloroethene (TCE) were also detected in these wells.

- Cidra Well #3 (Planta Alcantarillado), serving 112 people, closed in February 1999
- Cidra Well #4 (Calle Padilla Final), serving 177 people, closed in March 1996
- Cidra Well #6 (Calle Baldorioty), serving 207 people, closed in August 2000 (EPA 2003a)
- Cidra Well #8 (Frente Cementerio), not in service, closed in October 1996

At the time of the well closures, the source(s) of contamination in the wells were unknown, and several investigations were conducted to identify potential source areas. These investigations, summarized below, are described in the Expanded Site Inspection/Remedial Investigation Report (ESI) package prepared by Weston Solutions, Inc. (EPA 2003b).

1.4 Previous Site Investigations

EPA Pre-CERCLIS Screening Report, October 2000

In October 2000, EPA completed a Screening Report prior to listing the site in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). In support of the evaluation, EPA personnel conducted file searches, interviews, and field reconnaissance surveys at 31 sites in the area. Twenty-one sites were recommended for entry into CERCLIS.

EPA Expanded Site Inspection/Remedial Investigation, 2002

In June 2002, EPA's Region 2 Site Assessment Team (SAT) collected groundwater samples from the closed municipal supply wells and from 20 other active and inactive wells in Cidra. PCE was detected in the closed wells at concentrations ranging from 0.64 to 12 micrograms per liter (µg/L). PCE was also detected in two industrial/potable supply wells (IVAX No.1 and No.2) and three industrial wells (Glaxo Smith Kline No.1 and No.2 and Millipore - Cidra). Related chlorinated solvents, including 1,1-DCE; 1,1-dichloroethane (1,1-DCA); cis-1,2-dichloroethene (cis-1,2-DCE); carbon tetrachloride; and TCE, were also detected in groundwater samples. Maximum contaminant levels (MCLs) for PCE (5 µg/L) and 1,1-DCE (7 µg/L) were exceeded; however, the exceedances did not occur in active drinking water wells. Other VOCs were also detected, in most cases at estimated concentrations below the sample quantitation limits (SQLs). The investigation concluded that the Glaxo Smith Kline wells and Millipore-Cidra industrial wells are located east of Lago de Cidra and are likely not associated with the VOC source that has impacted the closed public supply wells.

The groundwater samples were also analyzed for semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and inorganic parameters. There were no detections of SVOCs, pesticides, or PCBs above laboratory quantitation levels. Inorganic parameters were not detected above MCLs in the groundwater samples, except thallium, which was reported at estimated concentrations above the MCL (2 µg/L) in three samples. Thallium is not known to be associated with the Cidra groundwater plume.

EPA Potential Source Area Investigation, 2003

In January and February 2003, EPA Region 2 SAT investigated 12 industrial sites in the Cidra area, to determine if they could be potential sources of contamination of the groundwater plume. Eleven of the sites are listed in EPA's CERCLIS Hazardous Waste Sites database, and one site is listed in the Archived Sites database.

Site Name	CERCLIS Number
International Dry Cleaners (IDC)	PRN000204340
Shellfoam Products (Shellfoam) (archived)	PRD987377264
SmithKlein Beecham Pharmaceuticals, Inc.	PRD090023250
Tech Group de Puerto Rico, Inc. (TGP)	PRN000204348
Zenith Laboratories Caribe, Inc. (ZEN)	PRD987377702

Excellent Laundry	PRN000204338
Creative Medical Corp.	PRN000204336
CMM Laundry	PRN000204330
Cidra Metal Caskets (CMC)	PRN000204335
Ramallo/Cidra Convention Center (CCC)	PRN000204333
CCL Label de Puerto Rico	PRN000204329
Caribbean Manufacturing Co.	PRN000204331

SAT used direct-push technology (DPT) to advance soil borings to depths just above the water table (approximately 40 to 60 feet bgs), and soil cores were retrieved from each borehole at 5-foot intervals. A groundwater sample was also collected with DPT at the TGP site. The soil and groundwater samples were field-screened for VOCs with the HAPSITE® Headspace Sampling System.

Field screening results indicated the presence of PCE, TCE, and trans-1,2-dichloroethene (trans-1,2-DCE) in soils collected from the IDC site from depths of two to seven feet bgs, at concentrations ranging from approximately 7 to 255 parts per billion (ppb). Other VOC detections included vinyl chloride in a sample from the Ramallo/CCC site and 1,1,2,2-tetrachloroethane (1,1,2,2-TCA) in a sample from the TGP site, both at concentrations less than 3 ppb. The field-screening data also indicated the presence of other VOCs in soil samples from some sites, mostly at concentrations below 1 ppb, and chloroform in the groundwater sample collected from the TGP site.

SAT used the screening results, particularly the PCE readings mentioned above, to select samples for VOC analysis through the Contract Laboratory Program (CLP).

The CLP analytical results confirmed the presence of PCE and other VOCs in soil at approximately four feet bgs at the IDC site, as follows: PCE at 11,000 micrograms per kilogram (µg/kg); TCE at 2,800 µg/kg; and cis-1,2-DCE at 5,100 µg/kg. These same VOCs were also detected in samples from seven feet bgs, but at lower concentrations, and cis-1,2-DCE was detected from the two feet bgs sample at 6,700 µg/kg. The PCE, TCE, and cis-1,2-DCE detections exceeded EPA's generic migration-to-groundwater Soil Screening Levels (SSL).

No detections were found in soil samples from the seven remaining facilities, and EPA recommended no further action (EPA 2003a).

SAT also collected two sediment samples from drainage channels at the Cidra Industrial Park. VOCs were not detected in the drainage channel samples. SAT also collected surface water and sediment samples from five locations in Lago de Cidra to evaluate the interconnection between the lake and the groundwater plume. Field-screening and CLP analytical results indicated that no VOCs were detected in the lake water and sediment samples.

1.5 Summary of the Remedial Investigation

Field investigation activities for the Cidra Groundwater Contamination Site RI were conducted from July 2007 through June 2012 (CDM Smith 2013). Field investigation activities included the following:

Stage 1 - July 2007 through January 2009

- Initial supply well sampling (Initial Round)
- Industrial facilities source area investigation
- Former dry cleaners source area investigation
- Borehole drilling and coring
- Borehole geophysical logging
- Packer sampling and packer testing
- Multiport monitoring well installation in the bedrock zone
- Groundwater elevation measurement (Stage 1)
- Monitoring well (bedrock) and supply well sampling (Stage 1)

Stage 2 - April to July 2010

- Source area soil investigation
- Monitoring well installation in the saprolite zone
- Groundwater elevation measurement (Stage 2)
- Monitoring well (bedrock and saprolite) and supply well sampling (Stage2)

Stage 2a - April to September 2012

- Additional monitoring well installation in the saprolite zone
- Groundwater elevation measurement (Stage 2a)
- Monitoring well sampling (Stage 2a saprolite wells only) (Stage 2a)
- Stream gauge installation and measurement
- Surface water and sediment sampling
- Vapor Intrusion Sampling

1.6 Physical Characteristics of the Study Area

1.6.1 Topography

The municipality of Cidra is located in the central-eastern section of Puerto Rico in the northern foothills of the Cordillera Central Mountain Range. The Cidra commercial district is approximately 1,400 feet above msl. The Cidra Industrial Park, which is slightly south of the commercial district, is approximately 1,345 feet above msl. Between and slightly west of these two areas is the Cidra cemetery. Topography generally slopes south from the commercial district to a narrow southwest-trending valley and unnamed stream. In the vicinity of the industrial park, topography slopes southwest toward the Rio Arroyata. The unnamed stream drains the area surrounding the Cidra cemetery, and flows into the Rio Arroyata southwest of the site; at this point, the Rio Arroyata forms the topographic low at approximately 1,310 feet above msl.

1.6.2 Surface Water and Drainage

The commercial center of the Cidra municipality is situated at the surface water drainage divide between Rio de la Plata and Rio de Bayamon drainage basins. Both the Rio de la Plata and Rio de Bayamon are major rivers that flow north to the Atlantic Ocean, approximately 20 miles north of the site. Several drainages (e.g., valleys) are present throughout the municipality and discharge either southwest into the Rio de la Plata or northeast into the Rio de Bayamon drainage basins.

In general, most of the surface water drainage from the site flows south and west across the site toward the unnamed stream and the Rio Arroyata, a tributary of Rio de la Plata. Areas to the north and east of the site drain into Lago de Cidra located 0.5 mile east of the site, which is part of the Rio de Bayamon drainage basin. This lake is a manmade reservoir and is a popular fishing destination. A surface water intake, located approximately 2.2 miles downstream of Lago de Cidra, serves approximately 20,000 people. The water is also used for watering commercial livestock. The site is located outside of the 500-year flood boundary.

1.6.3 Soil Characteristics

The majority of the soils across the area investigated during the RI are classified by the U. S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) as non-irrigated urban land mixed with approximately 25% Vega Alta Complex (Uv). The Vega Alta soils are fine-textured, iron-rich coastal plain sediments that are located on the toeslopes of terraces. They are typically well-drained soils with a high available water capacity. In undisturbed sequences, the top eight inches of these soils are a clayey loam, and beneath that is clay (USDA 2012).

The DJ Manufacturing, IVAX, and Pepsi, and the majority of the Shellfoam, Ramallo/Cidra Convention Center, ENCO properties are situated on the Daguey Clay (DaD). The Daguey Clay is characterized by NRCS as a very fine kaolinitic, isohyperthermic Inceptic Hapludox (USDA 2012). According to the University of Idaho, these soils are a type of Oxisol that are formed from highly weathered tuff breccia parent material. The soils are typically very low in nutrients and have a high phosphorus-fixing capacity. They typically consist of a mixture of kaolinite and iron oxide (hematite), which makes them stable and fairly resistant to soil erosion and runoff (soils.cals.uidaho.edu). This soil occurs on mountainous slopes and ridges across Cidra. The NRCS classifies the soil as being well-drained and having a high available water capacity. The top six feet are described as being predominantly clay, and beneath the clay is clayey loam (USDA 2012).

The Juncos Clay occurs in the southern portion of Cidra. The Juncos Clay is classified by the NRCS as a fine smectitic isohyperthermic Chromic Hapludert, a type of humid climate Vertisol (USDA 2012). The soil has a high shrink-swell capacity due to the type of clay it contains, which formed from the weathering of pyroclastic parent material (soils.cals.uidaho.edu). The soil occurs on hillslopes (toeslopes) and is comprised of approximately four feet of clay overlying competent bedrock. It is moderately well drained but has a low available water capacity and low permeability (USDA 2012).

1.6.4 Regional and Local Geology

The volcanic core of Puerto Rico is divided into three major geographic provinces. Cidra is located within the Central Volcanic Province, which is bound to the north by the left-lateral strike-slip Cerro Mula fault and contains numerous major strike-slip faults that parallel the Cerro Mula fault. The volcanoclastic strata are derived from subaerial volcanism that occurred on an elevated ocean floor. Intense strike-slip faulting complicated the deposition of the volcanic facies. Additionally, the strata are broadly warped by the east-trending Puerto Rico Anticlinorium (GSA 1998).

The three strata encountered at the site are the Quaternary-age terrace deposits composed of silt and clay, a saprolite layer (decomposed bedrock), and the underlying Cretaceous-age Pre-Robles volcanic rocks. The units are described below.

- **Quaternary Upper Silty Clay** – This unconsolidated overburden unit consists of reddish-brown silty clay grading to gray and brown silty clay. The depth to the bottom of the silty clay unit varies from 55 feet bgs at SMW-1 to 105 feet bgs at SMW-2; generally, the silty clay layer is thicker in the northern area near IDC (approximately 100 feet) than in the southern area by Ramallo/CCC (approximately 70 feet). Some evidence of dark brown to black-stained, remnant high angle fracture structures or lineations was observed in the silty clay at boring locations throughout the site. White to yellowish white very small crystals with a powdery appearance were observed in some of these lineations. These lineations were generally about four inches long and one-half inch in thickness and occurred at depths greater than 10 feet bgs and as deep as 70 feet bgs.

- **Saprolite Zone** – The saprolite is the result of chemical weathering of the underlying volcanic rocks. The material is a hard, wet, brown to light brown, sandy to silty clay with abundant dark brown to brown, angular to very angular, mafic rock fragments with fine-grained texture. The saprolite crumbles easily under light pressure. Where present, the unit ranges in thickness from 45 feet at MPW-2 and MPW-3 to 60 feet at MPW-1. The contact between the saprolite and underlying bedrock ranged from 109 to 156 feet bgs. At four locations, the depth ranged from 121 to 132 feet bgs.

- **Pre-Robles Volcanic Rock (Formation J)** - The core of the region is comprised of Cretaceous to Early Tertiary volcanic rocks of the Pre-Robles Formation (Formation J), which are the oldest rocks exposed in the Comerio geologic quadrangle. The rocks are estimated to be a maximum of approximately 2,700 meters thick and consist mostly of massive volcanic breccia, although lava flows and flow breccia occur throughout and are more common at the base and top of the unit. Massive to poorly stratified tuffs are interlayered with the volcanic breccia. Locally, volcanic conglomerates outcrop periodically (Pease and Briggs 1960).

The lower rocks of the Pre-Robles unit are comprised of dacite, feldspathic andesite, and pyroxene andesite. The middle rocks are comprised of feldspathic andesite and pyroxene andesite. The upper Pre-Robles rocks are predominantly pyroxene andesites. The upper and middle parts of the Pre-Robles rocks were described by Glover (1971) as coarse near-vent pyroclastic breccias, deposited in a marine environment while the lower part of the sequence was described as near- and distant-vent submarine ash-fall and pyroclastic flow deposits. Supply wells and the multiport monitoring wells are completed in this unit, and well logs describe it as blue, brown, or black volcanic rock. A rock core collected at MPW-5 from 123 to 328 feet bgs revealed the volcanoclastic rocks consist of well-defined dark bluish-gray to dark gray to dark reddish-brown clasts in a green fine-grained matrix with inclusions of light greenish gray and white crystals. Some 1/8-inch to 1/4-inch thick veins (possibly quartz) and 45-degree angle fractures (198 to 199 feet) were observed in the core. Evidence of metamorphism was observed at 202 feet.

1.6.5 Regional and Local Hydrogeology

Groundwater generally occurs in the fractured, consolidated volcanic rocks, with precipitation serving as the primary source of groundwater recharge. Precipitation percolates through the ground to the water table, and then moves in the consolidated rock through joints and fractures. The bedrock has little primary porosity (only two to three percent) but fractures can enhance groundwater flow considerably. The most productive wells in the bedrock are located in valleys where joints, fractures, and other openings are numerous and where recharge to bedrock is facilitated by topography and more permeable overlying unconsolidated deposits.

The Cidra site encompasses a small plateau where the commercial center is located, a drainage area to the south of town where the closed municipal wells are located, and a valley below the Cidra Industrial Park. The site is immediately underlain by the Quaternary silty clays, which overlie the fractured Cretaceous-age Pre-Robles volcanic bedrock, the major aquifer beneath the site. The saprolite zone lies between the silty clays and the bedrock. The hydrogeology of these units is described below.

Hydrogeology of the Quaternary Upper Silty Clay - Silts and clays have low permeabilities, which tend to hinder groundwater flow through the overburden to the groundwater table. However, the fractures and lineations observed in the silty clays may provide secondary permeability that enhances groundwater flow to the underlying units.

Hydrogeology of the Saprolite Unit –The saprolite zone below the silty clay was observed during Stage 2 well installation to be a major water-bearing unit; the saprolite stores water and provides recharge to the underlying bedrock aquifer. This unit is semi-confined by the overlying silty clay soils, as evidenced by rising water level conditions in drilling rods upon reaching this zone. During Stage 2 well installation activities, very little water was encountered while drilling through the silty clay unit. Once the saprolite unit and groundwater were encountered, water levels rose approximately 20 feet

(SMW-5) to 54 feet (SMW-2). Once in this unit, groundwater flows downward and laterally to the west/southwest and enters fractures at the top of the volcanic bedrock. No aquifer tests were performed on the saprolite during the RI.

Hydrogeology of the Pre-Robles Volcanic Rock - Groundwater flow in the bedrock is complicated by fractures and bedding planes and by the site location relative to the two major river basins. The porosity of the bedrock is only two to three percent, but joints and fractures can enhance groundwater flow considerably. Bedding planes in the bedrock act as individual aquifers, separated by aquitards consisting of relatively low permeability bedrock, where less fracturing is present. Across the majority of the site (west of IVAX), groundwater encounters bedding planes in the bedrock aquifer and flows laterally along strike (to the south) and then downdip (to the west). The resulting overall groundwater flow is to the west/southwest, toward the Rio Arroyata, located south and west of the site.

In the IVAX area, which is closer to the Arroyata Fault, bedding planes and fractures strike northwest/southeast, indicating a groundwater divide somewhere on the IVAX facility. Based on the different strike and dip orientations in this area, groundwater in the bedrock flows to the southeast, toward an unnamed stream southeast of IVAX.

Aquifer tests were not performed as part of the RI; however, well yields in the fractured volcanic rock in the Cidra vicinity are generally from 5 to 10 gallons per minute (gpm) or less (Miller et al. 1997).

1.6.6 Surface Water-Groundwater Interaction

Groundwater in the saprolite zone is hydraulically connected to the Rio Arroyata. During the RI, the potentiometric water levels at SG-1 and SG-2 in the Rio Arroyata were approximately 8 to 15 feet lower than in the adjacent saprolite monitoring wells SMW-6 and SMW-8, indicating that groundwater would tend to discharge to the river through seeps along the river bank or directly to the river. No seeps were observed during the surface water/sediment sampling event; however, water levels were high due to recent rain events, and any seeps may have been below the water level in the stream. Several groundwater seeps were observed during the ecological characterization reconnaissance along the banks of the Rio Arroyata downstream of Route 171.

1.6.7 Climate

The climate for Cidra, Puerto Rico is classified as tropical humid and is moderated by the nearly constant trade winds that originate in the northeast and its location in the foothills of the Cordillera Central Mountain Range. The average annual temperature for the Cidra area is 72.7° F. Precipitation data from 1981 to 2010 recorded at the Cidra 1 E rainfall station shows an average annual precipitation of 64.90 inches.

1.6.8 Population and Land Use

The Cidra site is located just south of the main commercial district of the Cidra Municipality in central eastern Puerto Rico. The Cidra Municipality is comprised of 36.5 square miles with a population of 43,480 and a population density of 1,200 people per square mile (2010 U.S. Census). Land use in the vicinity of the site includes forest (approximately 35 percent), agriculture/rural (approximately 50 percent), and urban (approximately 15 percent) (Ramos-Gines 1997). The land use in the vicinity of the site is primarily residential, commercial, manufacturing, and agricultural. The identified source areas are on Ramallo/CCC and IDC properties. The building on the Ramallo/CCC property is a former convention center and is currently vacant. This property is completely paved except for a strip of grass in front of the building. The building on the IDC property is a former dry cleaner on the first floor with tenants on the second floor. The first floor has a clearance of approximately eight feet. There is some exposed area in the main alley, but this property is also mostly paved. The buildings on the neighboring properties to IDC are occupied.

Wells located within a four mile radius of the site that draw water from the Pre-Robles volcanic rock aquifer serve a population of approximately 8,838 (EPA 2003a).

1.7 Ecology

An ecological reconnaissance was performed at the site on November 3, 2009 in accordance with the CDM Smith Final Work Plan Volume I (CDM Smith 2009). The field effort focused on areas which exhibited, at a minimum, marginal habitat suitable for supporting populations or ecological communities that may potentially be exposed to site-related contaminants via groundwater discharge. These areas consisted of aquatic and riparian habitats associated with the Rio Arroyata, a tributary of the Rio de la Plata, and two drainage areas which form the Rio Arroyata.

The portion of the Rio Arroyata included in the ecological reconnaissance can be characterized as a low/moderate gradient stream comprised of various riffle/run/pool sequences no more than three to five feet in width, with depth ranging from a few inches to over a foot in pooled reaches. Stream banks are relatively steep. Debris piles and eroded banks within bends suggest moderate to high flow during precipitation events. Substrate varies from coarse sand/fine gravel to coarse gravel and cobble within riffle and run areas; coarse sand comprises the majority of substrate found in deeper pools as these are associated with depositional areas along bends. Along the right bank downstream of the Route 171 bridge several groundwater seeps were observed.

In general, vegetative communities and available habitats are indicative of disturbed conditions as evidenced by former dilapidated structures and foundations, miscellaneous refuse, surrounding development, and the presence of native and non-native species. Tree canopy cover ranges from 85 to 100 percent within the immediate stream corridor of the Rio Arroyata and drainage swales. With the exception of areas characterized by monotypical stands of bamboo, understory is dense and consists of various woody and herbaceous vegetative species. Other than physical disturbances, no impacts that may potentially be related to site contamination are present.

Various wildlife was observed during the ecological reconnaissance, including several bird species, large terrestrial snails, lizards, frogs, and fish species.

Information regarding threatened and endangered species and ecologically sensitive environments that may exist at or in the vicinity of the site was requested from EPA and the Puerto Rico Department of Natural and Environmental Resources (PRDNER).

EPA reported that a review of United States Fish and Wildlife Service (USFWS) records indicate that two federally-listed species, the Puerto Rico boa (*Boa puertorriquena*) and the Puerto Rican Plain pigeon (*Paloma sabanera*), may be found within the municipality of Cidra. Neither species was encountered during the site visit.

PRDNER reported that a review of their records for the site and surrounding area indicated no known occurrences of listed rare, threatened, and/or endangered species.

1.8 Nature and Extent of Contamination

The nature and extent of contamination in site media was assessed by comparing analytical results to site-specific screening criteria. Figures 1-3 (a through e) through 1-13 display the data used to evaluate nature and extent. Five chemicals were identified as site-related contaminants in order to focus the discussion of contamination including PCE, TCE, cis-1,2-DCE, 1,1-DCE, and vinyl chloride. These chemicals were chosen based on the frequency and magnitude of screening criteria exceedances and previous detections in the supply wells:

Summary of Soil Contamination

- Site-related VOCs were detected in soil samples at IDC, Ramallo/CCC, CCL Label, ENCO, DJ Manufacturing Don Quixote, and ESSO. Soils only exceeded screening criteria at IDC and Ramallo; thus these sites are addressed in this FS.

- No VOCs were detected at the Coffee Shop or Ramoncito. A few VOCs were detected at IVAX, Pepsi, and Shellfoam, but at levels below screening criteria; none were site-related VOCs.

- The main source of contamination in the southern area of the site is at Ramallo/CCC with the highest levels of site-related contaminants found in shallow soils in the northeastern portion of the facility in RMSB-18 (PCE at 3,300,000 µg/kg and TCE at 2,700J µg/kg [0-4 feet bgs]).

- The highest levels of site-related contaminants in the northern drainage area were found at IDC (PCE at 1,700,000 µg/kg [4-8 feet bgs] and TCE at 39,000 µg/kg [4-6 feet bgs]); contaminant levels generally decrease with depth.

- Since volatilization is an important transport process for chlorinated VOCs in soil, vapor intrusion is a concern at Ramallo/CCC and IDC due to the high soil concentrations. Note that vapor and indoor air will not be addressed in this document, and will be addressed separately.

Summary of Soil Vapor Contamination

- PCE and TCE were present in subslab soil vapor at concentrations several orders of magnitude higher than their respective screening levels at both the IDC and Ramallo/CCC source areas. PCE was also detected in subslab soil gas samples at ENCO, CCL Label, Former 579 Store, and Praxedes Public Housing, indicating that PCE vapor has migrated in the subsurface to buildings closely proximal to the source areas.

- PCE, TCE, and cis-1,2-DCE vapors have migrated from subsurface into indoor air at the IDC, Former 579 Store, Ramallo/CCC, and Praxedes Public Housing properties. However, there are no indoor air screening level exceedances for these site-related contaminants. TCE was also detected in ambient air samples, suggesting that non-site related sources may have contributed to TCE found in indoor air.

- Several non-site-related VOCs, such as benzene, carbon tetrachloride, chloroform, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,2-dichloropropane, ethylbenzene, and 1,1,2,2-tetrachloroethane, were detected at levels above their respective screening levels in indoor air. The presence, concentrations, and distribution of VOCs in the subsurface, within buildings, and ambient air indicate that the VOC exceedances were mostly attributable to indoor sources and background levels rather than vapor intrusion.

Summary of Groundwater Contamination

- No exceedances were found in any of the wells in the northern drainage area (north of CCL Label). Low levels of site-related contaminants were detected at levels below the screening criteria.
- The groundwater contamination in the southern area originates at the Ramallo/CCC facility and extends southwest toward the Rio Arroyata.
- Overall, the highest levels of site-related contaminants in groundwater were detected in the saprolite wells located at and downgradient of Ramallo/CCC: SMW-10 (62-72 feet bgs) had a PCE concentration of 1,700 µg/L and a TCE concentration of 31 µg/L, and SMW-1(48-58 feet bgs) had a PCE concentration of 680 µg/L and a TCE concentration of 14 µg/L).
- Multiport well, MPW-5, adjacent to Cidra 8 had the highest levels and the most PCE exceedances in bedrock, with a maximum of 120 µg/L (260-274 feet bgs). TCE follows a similar pattern with the highest concentration (5.3 µg/L) occurring at 302-324 feet bgs.
- No dense non-aqueous phase liquids (DNAPLs) have been observed in groundwater at the site.

Summary of Surface Water/Sediment Contamination

- Groundwater in the saprolite zone is hydraulically connected to the Rio Arroyata; the contaminant plume extends to the Rio Arroyata, although it is unknown whether it extends under and southwest of the river.
- PCE, TCE, and cis-1,2-DCE were found at levels below screening criteria (5 µg/L for PCE and TCE and not listed for cis-1,2-DCE) in surface water samples collected from the Rio Arroyata.
- PCE was detected below its screening criterion (8,600 µg/kg) in one downstream sediment sample.

1.9 Contaminant Fate and Transport

The fate of a chemical in the environment is a function of its physical and chemical properties and conditions at the site. The potential for environmental transport is a function of the conditions at the site, including geological and hydrogeological characteristics. The primary fate and transport aspects of the site are summarized below.

- PCE and its degradation products have migrated from the ground surface through the vadose zone and into the groundwater. Some contaminant mass is likely retained by capillary forces in the pores, lineations, or fracture zones of the clay-rich soil at the Ramallo and IDC source areas.

- The greatest potential for the transport of the chlorinated VOCs is through continuous dissolution of contaminants in soil to groundwater, groundwater migration, and volatilization.

- Dissolved contaminants move with the groundwater flow in the saprolite toward the southwest and eventually discharge into the Rio Arroyata. Dissolved contaminants in the saprolite may enter shallow bedrock groundwater through bedrock bedding planes and fractures.

- Chlorinated VOCs in soil and groundwater may migrate as vapor. Vapor intrusion is a potential concern for occupied buildings at the site.

1.10 Conceptual Site Model

The CSM is developed to integrate all the different types of information collected historically and during the RI, including the site physical setting, the nature and extent of contamination, and contaminant fate and transport.

The two source areas identified at the site are discussed below.

Ramallo

Contaminants were likely discharged directly to the ground at the Ramallo source area.

- Contaminants spilled on the ground infiltrated into the clay, primarily through the lineations and fractures in the clay. Further contaminant migration is driven by rainfall, which infiltrates the clay along the same pathways. Contamination has likely diffused out of the lineations and fractures and into the clay matrix.

- PCE and its degradation products flow southwest with groundwater in the saprolite, as evidenced by PCE levels in SMW-10 and SMW-1 at 1,700 µg/L and 680 µg/L, respectively. The saprolite layer contains the highest levels of PCE in groundwater at the site, and recharges the underlying bedrock aquifer. Figure 1-14 shows the general orientation of the PCE contaminant plume in the saprolite zone, which extends horizontally to the Rio Arroyata.

- Contamination enters bedrock bedding planes and fractures just upgradient of MPW-1, as evidenced by PCE in shallow bedrock in this well. Contamination spreads along strike (primarily to the south), and downdip (west). MPW-5 and Cidra 8 are along this contaminant migration pathway, and exhibit contamination at deeper depths.

International Dry Cleaner

Contaminant transport at IDC is different Than at Ramallo.

- The majority of the surface in the vicinity of IDC is overlain by buildings and roads, which prohibit the majority of precipitation from infiltrating into the overburden. As a result, the bulk of precipitation drains via overland flow toward the northern drainage area. The remainder migrates downward through fractures and lineations in the soil in unpaved areas. This rainwater infiltration serves as a mechanism for contaminant transport to move deeper into the vadose zone. Contaminant transport through this unit may be hindered in this area due to greater overburden thickness and tighter soils at depth. Contamination has likely diffused out of the lineations and fractures and into the clay matrix.

- Low-levels of PCE and its degradation products eventually reach the saprolite zone, migrate to the top of bedrock, and enter the bedrock bedding planes and fractures. There is currently no groundwater contamination at IDC.

1.11 Cultural Resource Survey

CDM Smith's cultural resources subcontractor, Richard Grubb & Associates, conducted a Stage IA cultural resources survey for the site to assess the archaeological sensitivity of the area of potential effects (APE); the APE consists of approximately 144 acres in the Municipality of Cidra. The survey concluded that portions of the APE possess high and moderate sensitivity for archaeological resources; specific conclusions of the survey are presented below.

Historic evidence indicates that the Cidra Municipal Cemetery (Cemetery) was established in the APE at least by the 1880s. Grave markers at the western end of the Cemetery appear to exhibit evidence of having been relocated during expansions to the Cemetery. The precise boundaries of nineteenth century cemeteries are often not accurately depicted in historic records, and associated historic burials are often identified outside recorded cemetery limits. Areas near the Cemetery are assessed to possess a high sensitivity for historic burials.

Elsewhere, in the western and southern portion of the APE, zones of high and moderate sensitivity for archaeological resources have been delineated on the basis of cartographic evidence, field reconnaissance, and the review of geoprobe soil boring logs. Other portions of the APE possess extensive evidence of disturbance associated with previous earthmoving activities and are assessed to possess low sensitivity for the survival of intact archaeological resources. Parking lots and yard areas, however, within the northern portion of the low sensitivity zone and along Route 171, may possess potential for deep historic features such as wells or privies associated with nineteenth century structures depicted on historic maps in these areas.

1.12 Human Health Risk Assessment

The HHRA is developed to characterize potential human health risks associated with the site in the absence of any remedial action. The HHRA is conducted in accordance with current EPA guidance outlined in Risk Assessment Guidance for Superfund (RAGS), Parts A, D, E, and F and other EPA guidance pertinent to HHRAs.

Exposure Assessment

Based on the RI results, the site is divided into the following four exposure areas for soil for this risk evaluation.

- Exposure Area 1: Ramoncito, Don Quijote Pizza, Coffee Shop, and ESSO Gas Station/LM Auto Parts (ESSO)

- Exposure Area 2: IDC
- Exposure Area 3: CCL Label, Ramallo/ CCC, and ENCO
- Exposure Area 4: Shellfoam, DJ Manufacturing, IVAX, and Pepsi

Chemicals of potential concern (COPCs) are identified based on criteria outlined in RAGS, primarily through comparison to risk-based screening levels. Potential exposure pathways at the site are defined based on potential source areas, release mechanisms, and current and potential future uses of the site. Potential receptors evaluated in the risk assessment include:

- Current Land-Use Scenario
  - Workers, Trespassers, and Residents at Exposure Area 2
  - Workers at Exposure Areas 3 and 4
  - Recreational Users at Rio Arroyata
- Future Land-Use Scenario
  - Workers, Trespassers, Residents, and Construction Workers at All Exposure Areas
  - Recreational Users at Rio Arroyata

Exposure pathways evaluated for soil include ingestion of and dermal contact with soil, inhalation of particulates from soil by commercial/industrial workers, trespassers, residents, and construction workers. Exposure pathways evaluated for groundwater include ingestion of and dermal contact with groundwater, inhalation of vapor released during showering and bathing, and inhalation of vapor through vapor intrusion by commercial/industrial workers and residents. Exposure pathways evaluated for surface water and sediment include ingestion of and dermal contact by recreational users.

Quantification of exposure includes evaluation of exposure parameters that describe the exposed population (e.g., contact rate, exposure frequency and duration, and body weight). Daily intakes are calculated based on the reasonable maximum exposure (RME) scenario (the highest exposure reasonably expected to occur at a site). The intent is to estimate a conservative exposure case that is still within the range of possible exposures. Central tendency exposure (CTE) assumptions are also developed, when the estimated risks under RME scenario exceed EPA's threshold risk range. CTE scenarios reflect more typical exposures.

Toxicity Assessment

COPCs are quantitatively evaluated on the basis of their noncancer and/or cancer potential. The reference dose and reference concentration are the toxicity values used to evaluate noncancer health hazards in humans. Inhalation unit risk and slope factor are the toxicity values used to evaluate cancer health effects in humans. These toxicity values are obtained from various sources following the hierarchy order specified by EPA.

Risk Characterization

Risk characterization integrates the exposure and toxicity assessments into quantitative expressions of risks/health effects. To characterize potential noncancer health effects, comparisons are made between estimated intakes of substances and toxicity thresholds. Potential cancer effects are evaluated by calculating probabilities that an individual will develop cancer over a lifetime exposure based on projected intakes and chemical specific dose-response information. In general, EPA recommends target risk values (i.e., cancer risk of 10^{-6} [1 in a million] to 10^{-4} [1 in a 10,000] or noncancer health hazard index [HI] of unity) as threshold values for potential human health impacts. These target values aid in determining whether additional remedial action is necessary at the site.

The total hazard indices (HIs) for all current and future receptors, except current receptors at Exposure Area 2 and future trespassers at Exposure Area 1 under the reasonable maximum exposure (RME) scenario, are above EPA's threshold of unity (1). The current and future workers at Exposure Areas 3 and 4, the current and future recreational users and the future construction workers have noncancer HIs exceeding EPA's threshold under the RME scenario for the kidney and respiratory system due to exposure to vanadium in soil. Under the central tendency exposure (CTE) scenario, the total HIs are at or below EPA's threshold. The future residents have noncancer HIs exceeding EPA's threshold under the RME scenario for the cardiovascular system, central nervous system (CNS), developmental, heart, immune system, kidney, liver, lung, nervous system, respiratory system, skin, and thyroid due to exposure to PCE, 1,1,2-trichloroethane, TCE, arsenic, cobalt, and vanadium. Under the CTE scenario, the total HIs are still above EPA's threshold. The potential health hazards to the cardiovascular system, CNS, development, kidney, liver, lung, nervous system, respiratory system, and skin are due to exposure to arsenic, PCE, and vanadium in soil and groundwater. Risks associated with arsenic and vanadium are most likely overestimated.

Future residents may potentially be exposed to volatile COPCs via inhalation of vapor emanating from groundwater into enclosed structures via vapor intrusion and into ambient air via vaporization.

1.13 Screening Level Ecological Risk Assessment

A SLERA was conducted for the site to evaluate the potential for risk to ecological receptors from exposure to site media. Conservative assumptions were used to identify exposure pathways and, where possible, quantify potential ecological risks. The SLERA was prepared in accordance with the following documents:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final (EPA 1997)
- Guidelines for Ecological Risk Assessment (EPA 1998b)

The SLERA evaluated the potential for risk from exposure to chemicals through direct contact with site sediment and surface water via one assessment endpoint aimed at the protection of aquatic receptors utilizing the Rio Arroyata. All data used in the SLERA was collected in support of the RI. Sediment and surface water data were evaluated using a single maximum value of chemicals detected in each medium via comparison with media and chemical-specific ecological screening levels (ESLs).

Results of the SLERA indicated potential risk from exposure to several metals. In general, concentrations of these metals in background samples were either higher than, or similar to the maximum concentrations of metals detected in site sediment and surface water. The concentrations of metals detected are most likely reflective of natural conditions, or non site-related sources.

The site-related chemical PCE was detected in one sediment sample, and cis-1,2-DCE, PCE, and TCE were detected in surface water samples taken from the Rio Arroyata;. However, all concentrations were orders of magnitude below their respective ESLs. Therefore, the site poses no site-related risk to ecological receptors.

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Section 2

Development of Remedial Action Objectives and Screening of Technologies

RAOs are media-specific goals for protecting human health and the environment and serve as guidance for the development of remedial alternatives. RAOs must be identified as specifically as possible without unduly limiting the range of alternatives that can be developed for detailed evaluation. RAOs are based on regulatory requirements and risk based evaluations, which may apply to the various remedial activities being considered for the site.

The process of identifying the RAOs takes into consideration the following aspects:

- The identification of affected media and contaminant characteristics
- The evaluation of exposure pathways, contaminant migration pathways, and exposure limits
- The evaluation of chemical concentrations that will result in unacceptable exposure

PRGs are target chemical concentrations that the remedial action will need to achieve in order to protect human health and the environment. PRGs for the Cidra site were selected based on Federal or Commonwealth promulgated ARARs, risk-based levels, and background concentrations, with consideration also given to other requirements such as analytical detection limits and guidance values. These PRGs were then used as a benchmark in the screening of remedial technologies, the development and screening of remedial alternatives, and the detailed evaluation of alternatives.

2.1 Identification of Remedial Action Objectives

The media of concern at the Cidra site are contaminated soil, soil vapors, and groundwater. The main source of soil contamination in the southern area of the site is at Ramallo and in the northern area of the site is at IDC. The groundwater contamination is located in the southern portion of the site and originates at the Ramallo facility. Site-related contaminants are chlorinated aliphatic compounds, including PCE and the degradation products TCE, cis-1,2-DCE, 1,1-DCE, and vinyl chloride. These contaminants are VOCs and may pose risks to human health through inhalation, ingestion, and dermal contact.

To protect human health and the environment, RAOs are identified. However, site-specific constraints that can limit the implementation of remedial actions should also be considered. The site-specific HHRA indicates that the direct contact risks from exposure to site related contaminants at IDC and Ramallo are within EPA's acceptable risk range for current receptors. For all future receptors, except for residents and workers, the direct contacts risks for site-related contaminants are also within EPA's acceptable range. The HHRA determined there was a noncancer risk above EPA's acceptable risk range due to inhalation of PCE for future residents and workers at Ramallo. Since both locations are either residential or commercial areas, there are no suitable habitats for ecological receptors.

The RAOs for soil are:

- Prevent/minimize contaminated soil at the site from serving as a source of groundwater contamination by isolating or remediating soils with contaminant concentrations exceeding groundwater protection PRGs
- Prevent/minimize human exposure to soils having contaminant concentrations in excess of the PRGs

Soil vapor samples show elevated soil vapor under the building slabs but were below EPA's indoor air screening levels for the IDC and Ramallo buildings.

The RAO for soil vapor is:

- Mitigate impacts to public health resulting from existing, or the potential for, soil vapor intrusion into buildings at the site.

The RAOs for groundwater are:

- Prevent human exposure to contaminant concentrations in groundwater above levels that are protective of drinking water
- Restore the groundwater to drinking water quality to the extent practicable

These RAOs and the associated PRGs discussed below address site contaminants in soil and groundwater and the risks associated with these contaminants as identified in the risk assessments. Taking action to address these RAOs would also reduce or eliminate sources of contamination to groundwater.

2.2 Potential ARARs, Guidelines, and Other Criteria

PRGs are developed based on ARARs from federal and state/commonwealth environmental standards. Where standards do not exist or provide an adequate level of protection, PRGs are based on risk-based calculations of acceptable exposure levels. As required under Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 must be protective of human health and the environment and attain the levels or standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of Federal environmental laws and Commonwealth environmental and facility siting laws, unless waivers are obtained. According to EPA guidance, remedial actions also must take into account non-promulgated "to be considered" (TBC) criteria or guidelines if the ARARs do not address a particular situation.

The degree to which these environmental and facility siting requirements must be met varies, depending on the applicability of the requirements. Applicable requirements must be met to the full extent required by law. CERCLA provides that permits are not required when a response action is taken on-site. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) defines the term on-site as the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for the implementation of the response action (40 Code of Federal Regulations [CFR] 300.5). Although permits are not required, the requirements of the applicable permits will be met. On the other hand, only the relevant and appropriate portions of non-applicable requirements must be achieved, and only to the degree that they are substantive rather than administrative in nature.

CERCLA requires that on-site remedial actions attain or waive Federal environmental ARARs, or more stringent Commonwealth environmental ARARs, upon completion of the remedial actions. The purpose of ARARs is to define the minimum level of protection that must be provided by a remedy selected and implemented. Additional protection may be required, if necessary, to protect human health and the environment.

2.2.1 Definition of ARARs

Under CERCLA, as amended, a Federal or Commonwealth promulgated requirement may be either "applicable" or "relevant and appropriate" to a site-specific remedial action, but not both. The distinction is critical to understand the constraints imposed on remedial alternatives by environmental regulations other than CERCLA.

2.2.1.1 Applicable Requirements

Applicable requirements pertain to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental, Commonwealth environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those Commonwealth standards that are more stringent than Federal requirements may be applicable. Applicable requirements are defined in the NCP, at 40 CFR 300.5—Definitions.

2.2.1.2 Relevant and Appropriate Requirements

Relevant and appropriate requirements pertain to those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal environmental, Commonwealth environmental, or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site per se, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. Relevant and appropriate requirements are defined in the NCP, at 40 CFR 300.5—Definitions.

The determination that a requirement is relevant and appropriate is a two-step process that includes: (1) the determination if a requirement is relevant and (2) the determination if a requirement is appropriate. In general, this involves a comparison of a number of site-specific factors, including an examination of the purpose of the requirement and the purpose of the proposed CERCLA action, the medium and substances regulated by the requirement and the proposed requirement, the actions or activities regulated by the requirement and the remedial action, and the potential use of resources addressed in the requirement and the remedial action. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable (EPA 1988).

2.2.1.3 Other Requirements To Be Considered

These requirements pertain to Federal and Commonwealth criteria, advisories, guidelines, or proposed standards that are not generally enforceable but are advisory and that do not have the status of potential ARARs. Guidance documents or advisory TBCs may be used where no specific ARARs exist for a chemical or situation, or where such ARARs are not sufficient to be protective, to determine the necessary level of remediation to be protective of human health or the environment.

2.2.1.4 Classification of ARARs

Three classifications of requirements are defined by EPA in the ARAR determination process. ARARs are defined as chemical-, location-, or action-specific. Additionally, TBC criteria are also evaluated. TBC criteria are not federally enforceable standards but may be technically or otherwise appropriate to consider in developing site- or media-specific PRGs.

Chemical-specific ARARs and TBCs

Chemical-specific ARARs include those laws and regulations governing the release of materials possessing certain chemical or physical characteristics, or containing specified chemical compounds. These ARARs and TBCs usually are numerical values that are health- or technology-based values that establish concentration or discharge limits for specific chemicals or classes of chemicals. They also may define acceptable exposure levels for a specific contaminant in an environmental medium. They may be actual concentration-based cleanup levels, or they may provide the basis for calculating such levels. Examples of chemical-specific ARARs are polychlorinated biphenyl cleanup criteria for soils under the Toxic Substances and Control Act or MCLs specified for public drinking water that are applicable to groundwater aquifers used for drinking water. If more than one requirement applies to a chemical, compliance with the more stringent applicable ARAR is required. In the absence of ARARs, TBC criteria and guidance values are considered.

Location-specific ARARs and TBCs

Location-specific ARARs are design requirements or activity restrictions based on the geographical or physical locations of the site or area to be remediated and its surrounding area. Examples include areas in floodplains, wetlands wildlife habitats, areas where endangered species are present, historic sites, or areas of archeological significance. Location-specific criteria can generally be established early in the RI/FS process since they are not affected by the type of contaminant or the type of remedial action implemented.

Action-specific ARARs and TBCs

Action-specific ARARs are technology-based, establishing performance, design, or other similar action-specific controls and restriction to particular remedial actions. These regulations do not define site cleanup levels but do affect the implementation of specific remedial technologies. These action-specific ARARs are considered in the screening and evaluation of various technologies and process options in subsequent sections of this report.

ARARs and TBCs identified for the site are provided in Sections 2.2.2 through 2.2.4. Summaries of the potential ARARs and TBCs are provided in Tables 2-1 through 2-3.

2.2.2 Chemical-Specific ARARs and TBCs

Table 2-1 summarizes the chemical specific ARARs and TBCs identified for this site.

2.2.2.1 Federal Standards and Guidelines

Federal Screening Levels

- EPA Regional Screening Levels (RSLs) (November 2012). The land use at the site is mainly residential and commercial. EPA RSLs establish risk-based screening levels for the protection of human health and the environment, which will be considered in the development of the PRGs if there are no applicable standards.

Federal Drinking Water Standards and Regulations

- National Primary Drinking Water Standards (40 CFR 141). Groundwater at the site is classified as SG, suitable for drinking water use, and was historically used as a source of potable water supply. The groundwater use was terminated due to contamination. Federal primary drinking water standards are relevant and appropriate requirements to accommodate any future use of site groundwater as a drinking water source.

Federal Vapor Intrusion Guidance

- OSWER Vapor Intrusion Assessment: Vapor Intrusion Screening Level (VISL) Calculator Version 3.0, November 2012 RSLs.

2.2.2.2 Commonwealth Standards and Guidelines

Puerto Rico Water Quality Standards (PRWQS) Regulation

- PRWQS (March 2010). The purpose of the PRWQS is to preserve, maintain, and enhance the quality of waters of Puerto Rico and regulate any discharge of any pollutant to the waters of Puerto Rico by establishing water quality standards. Under the regulation, the “waters of Puerto Rico” include all coastal waters, surface waters, estuarine waters, ground waters and wetlands. The PRWQS are neither applicable nor relevant or appropriate chemical-specific ARARs. These standards will be evaluated under action-specific ARARs if any remedial alternatives under consideration entail any discharges to waters of Puerto Rico.

2.2.3 Location-Specific ARARs

Location-specific ARARs are those relevant to wetlands, flood plains, historical places, archaeological significance, endangered species, and wildlife habitats. The site is located outside of the 500-year flood boundary and no wetlands are within the study area.

The site is located within an ecological zone of Puerto Rico characterized by moist-lowland forest, and consists of the densely populated Cidra commercial district consisting of stores, private residences, municipal buildings and the town plaza. The municipality of Cidra is located in the central-eastern section of Puerto Rico in the northern foothills of the Cordillera Central Mountain Range. Another dominant land feature, a large cemetery, is also present. Vegetative communities and areas where ecological receptors may potentially be exposed within the remediation area are limited due to development and roads.

Information regarding threatened and endangered species and ecologically sensitive environments that may exist at or in the vicinity of the site was requested from EPA and PRDNER. The EPA reported that a review of USFWS records indicate that two federally-listed species, the Puerto Rico boa (*Boa puertorriquena*) and the Puerto Rican Plain pigeon (*Paloma sabanera*), may be found within the municipality of Cidra. Neither species was encountered during the site visit. PRDNER reported that a review of their records for the site and surrounding area indicated no known occurrences of listed rare, threatened, and/or endangered species.

A Stage 1A cultural resources survey was conducted for the site (RGA, February 2012) to assess the archaeological sensitivity of the APE. The survey concluded that portions of the APE possess high and moderate sensitivity for archaeological resources. Historic evidence indicated that the Cidra Municipal Cemetery was established in the APE at least by the 1880s. Areas near this cemetery were assessed to possess a high sensitivity for historic burials. Elsewhere, in the western and southern portion of the APE, zones of high and moderate sensitivity for archaeological resources have been delineated on the basis of cartographic evidence, field reconnaissance, and the review of geoprobe soil boring logs. Parking lots and yard areas, within the northern portion of the low sensitivity zone and along Route 171, may possess potential for deep historic features such as wells or privies associated with nineteenth century structures depicted on historic maps in these areas.

Table 2-2 summarizes the location-specific ARARs for this site. No Commonwealth location-specific ARARs were identified.

2.2.3.1 Federal Standards and Guidelines

The culture resource assessment revealed that the site was of high and moderate sensitivity for archaeological resources. There are no wetlands or floodplains within the site. Therefore requirements of Floodplain Management and Wetlands Protection will not apply. The Rio Arroyata is located downgradient of the site and should be considered during evaluation of remedial technologies for the site.

- National Historic Preservation Act (40 CFR 6.301)

2.2.4 Action-Specific ARARs and TBCs

Action-specific ARARs affect the implementation of specific remedial technologies. For example, although outdoor air has not been identified in the RI report as a contaminated medium of concern, air quality ARARs are listed below because some potential remedial actions may result in air emissions of toxic or hazardous substances. Table 2-3 summarizes the action-specific ARARs for this site.

2.2.4.1 Federal Standards and Guidelines

<u>General - Site Remediation</u>

- Occupational Safety and Health Administration (OSHA) Recording and Reporting Occupational Injuries and Illnesses (29 CFR 1904)

- OSHA Occupational Safety and Health Standards (29 CFR 1910)
- OSHA Safety and Health Regulations for Construction (29 CFR 1926)
- Resource Conservation and Recovery Act (RCRA): Identification and Listing of Hazardous Waste (40 CFR 261); Standards Applicable to Generators of Hazardous Waste (40 CFR 262); Standards for Owners/Operators of permitted hazardous waste facilities (40 CFR 264.10-264.19)

Transportation of Hazardous Waste

- Department of Transportation (DOT) Rules for Transportation of Hazardous Materials (49 CFR 107, 171, 172, 177, and 179)
- RCRA Standards Applicable to Transporters of Hazardous Waste (40 CFR 263)

Waste Disposal

- RCRA Land Disposal Restrictions (40 CFR 268)
- RCRA Hazardous Waste Permit Program (40 CFR 270)

Discharge of Groundwater or Subsurface Injection

- Federal CWA - National Pollutant Discharge Elimination System (NPDES) (40 CFR 100 et seq.)
- Federal Safe Drinking Water Act - Underground Injection Control (UIC) Program (40 CFR 144, 146)

Off-Gas Management

- Clean Air Act (CAA) - National Ambient Air Quality Standards (NAAQS) (40 CFR 50)
- Standards of Performance for New Stationary Sources (40 CFR 60)
- National Emission Standards for Hazardous Air Pollutants (40 CFR 61)
- Federal Directive – Control of Air Emissions from Superfund Air Strippers (OSWER Directive 9355.0-28)

2.2.4.2 Commonwealth of Puerto Rico Standards and Guidelines

General – Site Remediation

- PREQB Regulation for the Prevention and Control of Noise Pollution
- Puerto Rico's Anti-degradation Policy

Waste Disposal

- PREQB Regulation for the Control of Non-Hazardous Solid Waste (November 1997)

- PREQB Regulation for the Control of Hazardous Solid Waste (September 1998)

Discharge of Groundwater or Subsurface Injection

- PRWQS Regulation, March 2010

Off-Gas Management

- PREQB Regulation for the Control of Atmospheric Pollution (1995)

2.2.5 Corrective Action Management Units

A Corrective Action Management Unit (CAMU) may be required for alternatives at the site. The CAMU rule was specially intended for treatment, storage and disposal of hazardous remediation waste. Under the CAMU rule, EPA and authorized states may develop and impose site-specific design, operating, closure and post closure requirements for CAMUs in lieu of the minimum technology requirements (MTR) for land-based units. Although there is a strong preference for use of CAMUs to facilitate treatment, remediation waste placed in approved CAMUs does not have to meet Land Disposal Restriction (LDR) treatment standards. The main differences between CAMU and Area of Concern (AOC) policy are that, when a CAMU is used, waste may be treated ex-situ and then placed in a CAMU; CAMUs may be located in uncontaminated areas at a facility, and wastes may be consolidated into CAMUs from areas that are not contiguously contaminated. CAMUs must be approved by EPA as an applicable or relevant and appropriate requirement during a CERCLA cleanup using a record of decision.

2.2.6 Principal Threat Wastes

The NCP states the goal of the cleanup selection process is “to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste”. The NCP also establishes an expectation that EPA will use treatment to address the principal threat wastes posed by a site wherever practicable (NCP 300.430(a)(1)(iii)(A)). Principal threat wastes are those source materials considered to be highly toxic or highly mobile that cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

At both IDC and Ramallo, elevated concentrations of site-related VOCs were detected in the vadose zone. In particular, the elevated concentrations exceeded the soil saturation limit for PCE of 166 milligrams per kilogram (mg/kg), indicating the potential presence of DNAPL. PCE and other contaminants, to a lesser extent, have migrated to the saprolite and the bedrock aquifers at Ramallo. Therefore, PCE contamination in the vadose zone fits the definition of principal threat waste and would require remediation.

Note that contaminated groundwater generally is not considered to be source material; however, if present, DNAPL in groundwater may be considered as source material (EPA 1991). DNAPL has not been observed at the site.

2.3 Preliminary Remediation Goals

To meet the RAOs defined in Section 2.1, PRGs are developed to aid in defining the extent of contaminated soil and groundwater requiring remedial action. PRGs are chemical-specific remediation goals for each media and/or exposure route that are expected to be protective of human health and the environment. They are derived based on comparison to ARARs, risk-based levels, and background concentrations, with consideration also given to other requirements such as analytical detection limits, guidance values, and other pertinent information.

2.3.1 PRGs for Soil

No Federal or Commonwealth chemical-specific ARARs were identified for soil. EPA RSL criteria are TBC criteria. Since promulgated standards do not exist for the site-related contamination in soil, PRGs for soil were derived based on protection of groundwater for the site and risks to human health from PCE, whichever is lower. The contaminant cleanup level for protection of groundwater from PCE is more conservative than the contaminant cleanup level based on the human health risk.

Soil cleanup levels are set to be protective of groundwater. The concentration of contaminants in water leaching from the vadose zone should not lead to exceedances of groundwater PRGs. The soil PRGs were calculated using a site-specific soil-partitioning coefficient, K_d, and the standard Dilution-Attenuation Factor (DAF) of 20 (EPA 1996). The DAF considers dilution and attenuation factors that reduce contaminant concentrations in soil leachate during migration through the vadose zone. Table 2-4a presents the PRGs for soil based on impact to groundwater quality.

Even though the PRGs are the ultimate concentration goals for site cleanup, site-specific situations, in particular the deep contamination that exists in the clay formation and limitations on currently available treatment technologies may result in the remedial action not achieving the PRGs. As a result, the treatment technologies for this site would focus on hotspots. The hotspots are defined based on areas with levels of concentrations significantly higher than seen throughout the rest of the site, such as the area where principal threat waste is located. Containment technologies will be considered for the remaining areas.

2.3.2 Screening Criteria for Vapor Intrusion

Federal vapor intrusion guidance was identified. The suitable sub-slab contaminant screening criteria and indoor air concentration requiring mitigation were developed by EPA. The sub-slab screening criteria and indoor air concentration requiring mitigation are presented in Table 2-4b. Based on the results of vapor sampling conducted during the RI, EPA would install vapor mitigation systems at residences as necessary.

2.3.3 PRGs for Groundwater

Groundwater at the site is classified as SG (which includes all groundwaters as defined in Puerto Rico's Water Quality Standards Regulation [March 2010]), suitable for drinking water use, and was historically used as a source of potable water supply. In order to accommodate any future use of site groundwater as a source of potable water supply, federal drinking water standards are relevant and appropriate requirements. Puerto Rico Water Quality Standards (PRWQS) Regulation, which is a TBC, will be considered for groundwater if remedial alternatives under consideration entail any discharges to any waters of Puerto Rico. Table 2-4c presents the PRGs for groundwater.

Deed restrictions will be in place to prevent well installation and access to the groundwater which will protect people from exposure to contaminant concentrations over permissible limits. Over time, it is expected that the aquifer will eventually achieve PRGs through remedial actions and naturally occurring mechanisms such as dilution and dispersion.

2.4 Identification of Remediation Target Zones

Four site-related soil and groundwater contaminants are identified in Table 2-4a and 2-4c, respectively. These most widely detected contaminants, PCE, TCE, cis-1,2-DCE, and vinyl chloride are used as the target contaminants to define the site-specific cleanup areas. These contaminants are also detected at concentrations exceeding PRGs and are, therefore, used as the target contaminants for technology evaluation.

Two distinct areas of contamination have been identified at the site as discussed previously in Section 1. The soil and groundwater within these areas with concentrations that exceed the PRGs would require remediation, and are designated the remediation target zones. The two target zones are defined and described below. The boundary of each zone was estimated based on the concentration of the most widely detected contaminant exceeding its PRG in the groundwater or soil. The approximate areal extent of each target zone is shown in Figures 2-1, 2-2, and 2-3.

As shown in the figures, neither the vertical nor the horizontal extent of contamination was fully delineated during the RI.

Soil

- Ramallo. Contaminated soils were detected from the ground surface to the water table (the top of the saprolite, approximately 80 feet bgs). The areal extent of the target zone is estimated to be 16,000 square feet, corresponding to a volume of 47,400 cubic yards. However, treatment will be considered for the hotspot, which is inside the red dotted line shown on Figure 2-3.
- International Dry Cleaners. Contamination has been detected in soils beneath the IDC building. No soil borings were advanced to the water table (the saprolite) during the RI due to access and space limitations. However, given the similarity in soil type between Ramallo and IDC, it is conservatively assumed for this FS that soils from the ground surface to the top of the saprolite (106 feet bgs) at IDC are contaminated above the PRGs. The areal extent of the target zone is estimated to be 850 square feet, corresponding to an approximate volume of 3,300 cubic yards. However, treatment will be considered for the hotspot, which is mainly in the alley way, as shown on Figure 2-2 inside the red dotted line.

Groundwater

- Saprolite Plume: The source of this plume is soil contamination at Ramallo. The plume is believed to extend southwest from Ramallo to the Rio Arroyata. The groundwater target zone is bound by PCE concentrations above the PRG (5 µg/L) in the saprolite hydrostratigraphic unit.

Given the detected presence of site-related contamination in the underlying bedrock, it is assumed that the entire thickness of saprolite inside the 5 µg/L isocontour shown on Figure 2-1 is contaminated above the PRGs. This corresponds to an estimated areal extent of 406,400 square feet and an assumed thickness of 50 feet.

- Bedrock Plume: The source of this plume was initially soil contamination at Ramallo. For purposes of developing remedial alternatives, it is conceptually helpful to consider the saprolite plume as the source of bedrock contamination, since contamination enters the bedrock bedding planes at the bottom of the saprolite hydrostratigraphic unit. Bedrock contamination has been identified in wells MPW-5 and MPW-1 (Figure 1-14). No calculation of treatment zone volume has been completed for the bedrock since groundwater flow is in bedding planes, and not a porous matrix.

2.5 General Response Actions

GRAs are broad categories of actions that may satisfy the RAOs and that characterize the range of remedial responses appropriate to the media of concern at the site. Following the development of GRAs, one or more remedial technologies and process options were identified for each general response action category. Although an individual response action might be capable of satisfying the RAOs alone, combinations of response actions are usually required to address site contamination adequately. GRAs applicable to this site are described below.

2.5.1 No Action

The NCP and CERCLA require the evaluation of a No Action alternative as a basis for comparison with other remedial alternatives. Under the No Action alternative, no remedial actions are implemented, the current status of the site remains unchanged, and no action would be taken to reduce the potential for exposure to contamination.

2.5.2 Institutional/Engineering Controls

Institutional Controls are administrative and legal restrictions intended to control or prevent present and future use of contaminated media. Institutional controls are not intended to substitute for engineering aspects of a selected remedy. Engineering controls (e.g., fencing) are physical restrictions intended to control or prevent present and future access to contaminant media.

These limited measures are implemented to provide some protection of human health and the environment from exposure to site contaminants. Monitoring, which includes sampling and sample analysis, is typically used with Institutional/ Engineering Controls. Institutional/Engineering Controls are generally used in conjunction with other remedial technologies; alone they are not effective in preventing contaminant migration or reducing contamination.

2.5.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) refers to the remedial action that relies on naturally occurring attenuation processes to achieve site-specific remediation goals within a reasonable time frame. Natural attenuation processes that reduce contaminant concentrations in soil and groundwater include destructive (biodegradation and oxidation/reduction reactions with other subsurface constituents) and nondestructive mechanisms (precipitation, dissolution, adsorption and desorption). Extensive modeling and monitoring are typically performed as part of an MNA response action to demonstrate that contaminants do not represent significant risk and that natural attenuation is occurring at a sufficient rate to meet the RAOs.

2.5.4 Containment

Containment actions use physical or low permeability barriers and/or groundwater extraction wells or trenches to minimize or eliminate contaminant migration and to eliminate the exposure pathways to the human health and the ecologic system. Containment response actions can be in-situ or ex-situ and are typically used at the source area.

For soil contamination, in situ containment generally refers to a cover or cap system that may also include a vertical barrier. These caps reduce infiltration of precipitation and therefore minimize the opportunity for precipitation-derived water from coming into contact with contaminants. Containment response actions minimize direct human contact with contaminated soil, control volatilization or windblown dispersion of contaminants into air, and reduce infiltration of leachate into groundwater.

In addition to physical barrier containment, contaminants can also be hydraulically contained via operation of groundwater extraction wells/trenches. A groundwater extraction system installed downgradient from the contaminant source area could prevent the further migration of contaminated groundwater. Extracted groundwater is generally treated ex-situ. Low permeability walls (e.g., slurry walls or sheet piling) can also be installed in combination with groundwater extraction wells/trenches to reduce the volume of groundwater requiring pumping. Containment response actions minimize direct human contact with contaminated groundwater.

Containment technologies do not involve treatment to reduce the toxicity or volume of contaminants. The response actions require long-term monitoring to determine whether containment actions are performing successfully. The NCP does not prefer containment response actions since they do not provide permanent remedies and do not use treatment.

2.5.5 Removal or Extraction

Removal response actions refer to methods typically used to excavate and handle soil, sediment, waste, and/or solid materials. Excavation technologies provide no treatment of wastes, but may be used prior to treatment or disposal to remove wastes from designated areas. Removal technologies would be considered support technologies for treatment and disposal response actions.

Groundwater extraction provides hydraulic control to prevent migration of dissolved contaminants. Groundwater extraction is typically combined with ex-situ treatment and discharge response actions to achieve the RAOs. Groundwater extraction response actions provide reduction in mobility and mass of contaminants by removing the contaminants from the subsurface using groundwater extraction wells or interceptor trenches.

2.5.6 Treatment

Treatment involves the destruction of contaminants in the affected media, transfer of contaminants from one media to another, or alteration of the contaminants, thereby making them innocuous. The result is a reduction in toxicity/mobility/volume (T/M/V) of the contaminants. Treatment technologies vary among environmental media and can consist of chemical, physical, thermal, and biological processes. Treatment can occur in the subsurface or above ground. This GRA is usually preferred unless site or contaminant-specific characteristics make it infeasible from a constructability perspective, or if it is cost prohibitive.

2.5.7 Disposal/Discharge

Disposal response actions for soil involve the placement of excavated soil in an offsite facility permitted for the specific waste type, or backfill onsite if treated to regulatory limits.

Discharge response actions for groundwater involve the discharge of extracted groundwater via on-site injection, on-site surface recharge or surface water discharge following treatment to meet regulatory discharge and disposal requirements, or discharge to a publicly-owned treatment works (POTW) if pre-treatment standards are met.

2.6 Identification and Screening of Remedial Technologies and Process Options for Soils

For each GRA, various remediation options or technologies are used to carry out the response action. The term technology refers to general categories of remediation methods. Each technology may have several process options, which refer to the specific material, equipment, or method used to implement a technology. These technologies describe broad categories used in remedial action alternatives, but do not address details, such as performance data, associated with specific process options.

The technology screening approach is based upon the procedures outlined in Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA 1988). This evaluation process uses three criteria: effectiveness, implementability, and relative cost. Among these three, the effectiveness criterion outweighs the implementability and relative cost criteria. These criteria are described below:

<u>Effectiveness</u> - This evaluation criterion focuses on: 1) the effectiveness in extracting, treating and/or handling by other means (e.g., in-situ treatment or natural attenuation) the estimated volume of contaminated soil, and the ability to meet the remediation goals; 2) the potential impacts to human health and the environment during the construction and implementation phases; and 3) how proven and reliable the process options are expected to be with respect to the contaminants and conditions at the site.

<u>Implementability</u> - This evaluation criterion includes: 1) the technical and administrative feasibility of implementing the remedial system components and 2) the amount of space needed for treatment and disposal facilities, piping discharge runs, available space, accessibility, and available vendors.

Relative Cost - Cost plays a limited role in the screening process. Both capital and operation and maintenance (O&M) costs are considered. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are low, moderate, or high relative to the other options within the same technology type.

The soil remedial technologies considered (both screened out and retained) are briefly described in Table 2-5. Remedial technologies and process options that could achieve the RAOs, either alone or in combination with other technologies and process options, were used to develop the alternatives discussed in Section 3.

2.6.1 No Action

Under the No Action response action, no remedial actions will be conducted to reduce exposure to the contaminated soil.

Effectiveness – The effectiveness of No Action will be low because the RAOs will not be met.

Implementability – No Action is easy to implement from a technical perspective, and no significant administrative difficulties are expected.

Relative Cost – There is no cost for this response action.

Conclusion – No Action is retained as a baseline for comparison to other alternatives, as required by the NCP.

2.6.2 Institutional/Engineering Controls

Institutional controls consist of legal and administrative actions which control the use of the site to prevent exposure to contaminants. Engineering controls consist of installation of engineering systems to prevent or reduce exposure to contaminants. Institutional controls and engineering controls do not reduce the T/M/V of contamination, but can be implemented to reduce the probability of exposure to contaminants. Institutional/engineering controls generally require long-term monitoring of contaminant concentrations and migration.

2.6.2.1 Land Use Controls

Land use controls generally identifies the land use restrictions, describes the institutional/engineering controls that prevent human exposure to contamination at an unacceptable risk level, and specifies the frequency of inspection and monitoring which ensures the effectiveness of the institutional/engineering control system. Land use controls could be used to prevent subsurface intrusive activities (e.g., digging of soil), limit irrigation above the contaminated areas to minimize contamination leaching to groundwater, and limit the type or feature of new construction in contaminated areas (such as installation of a vapor mitigation system).

Effectiveness – Land use controls, when properly enforced and executed, would aid in prevention of human exposure to contaminated soil at unacceptable levels. However, land use controls will not prevent contamination in the vadose zone from migrating to the groundwater or reduce the T/M/V of the contaminated media.

Implementability – Land use controls would limit the current and future use of contaminated property and could potentially be difficult to enforce over the long term by a local government.

Relative Cost – The cost to implement land use controls is low.

Conclusion – Retained for further consideration.

2.6.2.2 Fencing and Signage

Fencing installed around contaminated areas limits access and minimizes direct human exposure to contaminated soil. Fencing is often installed with accompanying signage which indicates the risks of exposure. Fencing may also be used in combination with other remedial technologies to protect human health during remedial construction activities, such as excavation/removal.

Effectiveness – Fencing can be effective to minimize, if not prevent, human contact with the contaminated materials. However, fencing will not prevent contamination in the vadose zone from migrating to the groundwater or reduce the T/M/V of the contaminated media.

Implementability – This option could be easily implemented.

Relative Cost – This option has relatively low capital cost and low O&M cost.

Conclusion – Fencing and signage will be retained for further consideration in combination of other remedial options.

2.6.2.3 Monitoring

Monitoring includes periodic sampling and analysis of the impacted media—groundwater and soil—and other media at risk of impact. It may be conducted parallel with and/or after the completion of active remediation if contaminants exceeding the PRGs remain on site and are allowed to naturally attenuate. This program would provide data and evidence of the breakdown and/or movement of the contaminants and the progress of remedial activities. Monitoring can be implemented for short duration or long-term.

Effectiveness - Monitoring alone would not be effective in reducing the T/M/V of the contaminated media, and would not prevent contamination in the vadose zone from migrating to the groundwater at this site. However, a properly designed monitoring program would be effective in providing information on site conditions to decision makers.

Implementability – Monitoring is a proven and reliable process, and can be easily implemented.

Relative Cost – Monitoring involves low capital and moderate O&M costs.

Conclusion – Monitoring will be retained for further consideration.

2.6.3 Monitored Natural Attenuation

MNA refers to the remedial action that relies on naturally occurring attenuation processes to decrease contaminant concentrations and to achieve site-specific RAOs within a reasonable time frame. Natural attenuation processes that reduce contaminant concentrations in soil include destructive (biodegradation and chemical reactions with other subsurface constituents) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption).

Biodegradation usually occurs under saturated, anaerobic conditions where there is sufficient organic carbon to support a community of dehalogenating bacteria. The IDC and Ramallo vadose zones are above the water table and thus not always saturated. However, the soils are not completely dry: average soil moisture measured was 28% at IDC and 31% at Ramallo. The moisture data indicates that there may at times be sufficient moisture to support a microbial community capable of biodegrading site contaminants.

<u>Effectiveness</u> – MNA is effective where natural attenuation mechanisms have been shown to be able to meet the RAOs within a reasonable timeframe. At both IDC and Ramallo, anaerobic degradation products of PCE were detected in some samples, suggesting that biodegradation had occurred and there was sufficient moisture in the subsurface for anaerobic biodegradation. Vinyl chloride was detected at some samples in both these areas, indicating the presence of *Dehalococcoides spp.* (DHC). Cometabolic degradation is not effective for PCE. No evidence has been collected to indicate that abiotic degradation has been occurring. The conclusion is that there is not sufficient evidence to indicate that MNA is occurring in all areas of soil contamination above the PRGs.

<u>Implementability</u> – MNA is implementable. Materials and services necessary to model and monitor the contaminant dynamics are readily available. However, characterizing the destructive and non-destructive mechanisms governing MNA, especially in the vadose zone soil, can be complex. It is difficult to characterize subsurface soil gas transport (e.g. mass lost by volatilization) and biodegradation in soils that are only intermittently wet (e.g. mass lost by biodegradation). Long-term monitoring is usually implemented as part of a MNA alternative to prior to achieving the PRGs.

<u>Relative Cost</u> – MNA and associated modeling involve low capital costs and medium O&M costs for long-term monitoring and periodic reassessment costs.

<u>Conclusion</u> – MNA will not be retained because it is not anticipated to be effective at meeting the RAOs at this site within a reasonable timeframe.

2.6.4 Containment

Containment technologies are implemented to reduce contaminant mobility but do not directly impact contaminant toxicity and volume. However, by reducing contaminant mobility, exposures to human and ecological receptors are minimized or eliminated. Containment technologies are typically accompanied by a long-term O&M and monitoring program to verify that the containment measures continue to be effective. The commonly used containment technologies include capping, sheet piles, and slurry walls. Sheet piles and slurry walls are generally used for containing contamination below the water table. This section focuses on contamination in the vadose zone; therefore, sheet piles and slurry walls are not discussed here.

2.6.4.1 Capping

Capping can isolate contaminated media from direct contact with humans, biota, or surface runoff. Additionally, an impermeable surface cap can significantly reduce the infiltration of precipitation and stormwater into the contaminated soil, thereby reducing the potential for contaminants to leach from the vadose zone into the groundwater.

Effectiveness – Installation of a cap would be effective in preventing direct contact with contaminated soil. A properly designed, installed, and maintained low-permeability cap would be effective in minimizing stormwater infiltration that would induce contaminant migration from the vadose zone to the groundwater, thus reducing the mobility of contaminants. Capping would not eliminate migration due to movement via diffusion, but migration through diffusion is a slow process. Capping would also not reduce the toxicity and volume of the contaminated media. At both Ramallo and IDC, the buildings and pavement are already significantly capping the area and mass has still migrated deep into the vadose zone. This indicates that even if infiltration would be further reduced, the existing mass would continue to leach into groundwater (at Ramallo), even though at a much slower rate, well into the future, with the possibility of it leaching into the groundwater at IDC.

Implementability –Caps could be installed using conventional earth-moving construction equipment at both Ramallo and IDC. Current on site buildings and pavement could be integrated in the cap design. Capping would limit future land use and would require a rigorous inspection and maintenance program. Capping as a remedy generally requires that land use controls be implemented.

Relative Cost – Capping involves moderate capital and low O&M costs.

Conclusion – Capping will be retained.

2.6.5 Removal

Excavation technologies use standard earthwork equipment to remove contaminated soil for consolidation, treatment, and/or disposal. In general, heavy machinery (e.g. backhoes, bulldozers, end-loaders) can be utilized to remove large quantities of soil; manual excavation is useful for removal of small amounts of soil at sensitive areas (such as next to utilities) or when heavy machinery cannot access to certain areas. Implementation of this technology becomes more difficult and complicated with increasing depth due to accessibility, structural stability and safety concerns. Dewatering would be required for excavation below the water table. Once excavated, the materials have to be stored or stockpiled in a contained area to prevent contaminant migration or volatilization prior to disposal.

Effectiveness: – Removal alone would not be able to meet RAOs at the entire site because the soil contamination extends to over a hundred feet bgs – beyond the feasible depth of excavation at IDC and Ramallo, where neighboring buildings restrict the width of the excavation. Excavation to a shallower depth (such as less than 20 feet) would be effective; shallow excavations would need to be combined with other technologies to meet RAOs at the site.

Implementability: –Excavation would require sheet piling to provide structural support for neighboring buildings. The urban environment at this site is not conducive to excavation as the proximity of neighboring buildings to the contaminated area decreases implementability of this technology. Additionally, there is no open area available to stage the excavated soil at IDC. An off-site property would need to be procured. The excavated material would require treatment and/or disposal technologies. If the soil is classified as hazardous waste, it would need to be shipped elsewhere since there are no hazardous waste landfills in operation in Puerto Rico.

Relative Cost: – Excavation is considered to have high capital cost. It does not require O&M costs.

Conclusion: – Shallow excavation is retained.

2.6.6 Treatment

2.6.6.1 Thermal Remediation

In situ thermal remediation technologies heat the subsurface soil resulting in desorption and volatilization of contaminant compounds. Volatilized contaminants are extracted from the subsurface using a vapor recovery system, and treated prior to discharge to the air. Thermal technologies are attractive because they are very effective in heterogeneous and low-permeability soil conditions and generally require shorter treatment times (months) compared to many other remedial technologies. However, in-situ thermal treatment could also involve an extensive drilling program and high overall costs. Both electrical resistance heating (ERH) and thermal conductive heating (TCH) are thermal technologies potentially applicable for conditions observed at the site. Therefore, ERH and TCH are discussed in this report.

2.6.6.1.1 In Situ Electrical Resistance Heating (ERH)

ERH is a thermal remediation technology in which electrical current is passed through the soil to elevate subsurface temperatures. Electrodes are installed in wells throughout the treatment zone, and current is passed between the electrodes through the soil. As the matrix is heated, adsorbed and liquid phase contaminants begin to volatilize. Soil vapor extraction is combined with ERH to remove the contaminated vapors produced. Vapors are treated using an off-gas treatment system prior to being discharged to the atmosphere.

Effectiveness: – ERH is effective at targeting VOC contamination in heterogeneous and low-permeability soil conditions, such as those observed at Ramallo and IDC. ERH must be combined with soil vapor extraction (SVE) to remove the volatilized contaminants to prevent cooling and re-condensation in the subsurface, or migration into the ambient air or nearby structures. Sufficient moisture content in the vadose zone must be present for conduction of electricity. The moisture content at the site is anticipated to be suitable for ERH. However, areas of low moisture content can impact uniformity of electrical conductivity and contaminant removal, and moisture content may decrease as the subsurface is heated. Thermal remediation becomes less effective when the treatment zone receives fresh inputs of water from stormwater infiltration; energy will be lost in heating this superfluous water. In both areas, effectiveness could be increased by limiting stormwater infiltration during treatment.

Implementability: – This technology is implementable for targeting the contamination at Ramallo. The technology would require a significant, reliable source of electrical power. ERH electrodes and SVE capture wells could be installed through the building slabs to the depth of contamination. However, an aboveground treatment system is needed for in situ thermal remediation (ISTR). Space constraints at IDC would make it difficult to have a treatment system nearby. For health and safety reasons, access will be restricted to the treatment areas during treatment, potentially for over a year.

Relative Cost: – The capital and O&M costs for this technology are high.

Conclusion: – ERH will be retained for further consideration.

2.6.6.1.2 In Situ Thermal Conductive Heating (TCH)

TCH is a thermal remediation process that uses an array of heated vertical steel wells to elevate subsurface temperatures. Heat originating from the heating elements is transferred to the subsurface primarily via thermal conduction and radiant heat transport, which dominates near the heat sources. As the matrix is heated, adsorbed and liquid phase contaminants begin to volatilize. The heating desiccates the soil, providing pathways for the movement of volatilized contaminants. Soil vapor extraction is combined with TCH to remove the contaminated vapors produced. Vapors are treated using an off-gas treatment system prior to being discharged to the atmosphere.

Effectiveness: – TCH is effective at targeting and removing VOC contamination in heterogeneous and low-permeability soil conditions, such as those observed at the site. TCH must be combined with SVE to remove the volatilized contaminants to prevent cooling and re-condensation in the subsurface, or migration into the ambient air or nearby structures. TCH may be more effective than ERH in targeting vadose zone contamination due to the greater uniformity of thermal conductivity than electrical conductivity (which is dependent on soil moisture content). Thermal remediation becomes less effective when the treatment zone receives fresh inputs of water from stormwater infiltration; energy will be lost in heating this superfluous water. In both areas, effectiveness could be increased by limiting stormwater infiltration during treatment.

Implementability: – This technology is implementable for targeting the contamination at Ramallo. The technology would require a significant, reliable source of electrical power, fuel, or natural gas. ERH electrodes and SVE capture wells could be installed through the building slabs to the depth of contamination. However, an aboveground treatment system is needed for ISTR. Space constraints at IDC would make it difficult to have a treatment system nearby. For health and safety reasons, access will be restricted to the treatment areas during treatment, potentially for over a year.

Relative Cost: – The capital and O&M cost for this technology is high.

Conclusion: – TCH will be retained for further consideration.

2.6.6.1.3 Ex Situ Incineration

High temperatures (approximately 2000 °F) are used to volatize and combust halogenated organics in hazardous wastes. The destruction and removal efficiency for properly operated incinerators exceeds the 99.99% requirement for hazardous waste. Off gases and combustion residuals generally require treatment. This can be conducted either on site or off site.

Effectiveness: – This technology protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Treated soil would be backfilled or disposed following incineration.

Implementability: – This technology is difficult to implement due to limited availability of equipment and operators. There may be difficulty obtaining local acceptance to site an incinerator for onsite treatment.

Relative Cost: – The capital cost for this technology is high. It does not require O&M costs.

Conclusion: – Ex situ incineration is eliminated from further consideration due to cost and implementability issues concerning availability of equipment and personnel.

2.6.6.1.4 Ex Situ Low Temperature Thermal Desorption

Ex situ low temperature thermal desorption is a physical separation process that uses low temperatures (300-600 °F) to volatilize organic materials which can be treated or recycled. A carrier gas or vacuum systems captures and transports volatized water and organics to an off-gas treatment system.

Effectiveness: – This technology protects receptors by eliminating exposure to contaminants and reducing contaminant concentrations. Clay and silty soils and high humic content soils increase operating times as a result of binding of contaminants. Particle size can reduce performance of technology so soil may need to be pre-screened and re-worked.

Implementability: – The equipment and labor resources needed to implement this technology are somewhat readily available. Installation of equipment requires specialized technical personnel. Off-gas treatment may be required for dust and vapor emissions. Difficulties meeting air discharge requirements may be encountered. Due to high contaminant concentrations, energy requirements will be high to maintain the heating system. Process has intensive startup and monitoring requirements.

Relative Cost: – The capital cost for this technology is high. O&M costs are low.

Conclusion: – This technology is retained for further consideration.

2.6.6.2 Soil Vapor Extraction

An SVE system applies a vacuum to soil to remove volatilized contaminants, while also enhancing the volatilization of contaminants. Vapor extraction can be conducted ex situ on excavated soil using perforated pipes in the mounds, or in situ with vapor extraction wells. The extraction systems are coupled with blowers or vacuum pumps to create vacuum. Increased air flow through the soil allows enhanced mass transfer from adsorbed, dissolved, and free phases in the soil to the vapor phase. An off-gas treatment system is often utilized to treat the contaminated vapor prior to discharge to the atmosphere. Depending on the depth of soil being remediated, vertical extraction wells, horizontal extraction pipes, or trenches may be used. Surface caps are often used in conjunction with SVE to reduce emissions of fugitive vapors, or increase the vacuum radius of influence, or prevent surface water infiltration and vertical short-circuiting of air flow.

Effectiveness – The effectiveness of SVE can be limited when applied in damp, low-permeability soil conditions, such as those observed at IDC and Ramallo. The low-permeability of site soils in general will require very high vacuum pressures to induce airflow. The effectiveness and efficiency of in situ

SVE can be increased to an extent following pneumatic fracturing, as described below. Additionally, the effectiveness of SVE can be substantially increased when paired with the thermal remediation technologies, as the increase in temperature of subsurface results in significant increase in vapor pressurization and mobility.

The effectiveness of SVE on vadose zone soils is also dependent on total organic carbon and moisture content. The organic carbon content is not unusually low at the site, resulting in the potential for sorbed mass of VOCs—a characteristic that will reduce the effectiveness of SVE. The moisture content is approximately 30%. This means the clay is relatively damp, and SVE would be less effective.

SVE systems are typically operated in continuous or pulsed pumping mode until concentrations in the extracted vapors either drop to non-detectable levels or low asymptotic levels. Full contaminant removal would be difficult to achieve due to the low-permeability soils, sorption, and matrix diffusion.

Implementability – This technology is implementable for targeting the contamination at Ramallo and IDC. Vapor extraction wells could be installed through the building slab or in the dirt areas. Ex situ SVE could be implemented on excavated soil piles. Due to space limitations, the buildings on the treatment zone footprint may need to be modified to free up space for a treatment system and to allow drill rigs to enter. The periodic inflow from rainfall and stormwater runoff would result in decreased SVE effectiveness and temporary system shutdowns. If a cap were to be utilized to prevent infiltration, a stormwater management design and a stormwater diversion permit may be required. SVE is considered implementable.

Relative Cost – SVE involves low capital and low O&M costs.

Conclusion – SVE will be retained for further consideration.

2.6.6.3 Amendment Delivery

Amendment delivery is not a treatment technology, but is an important consideration for the feasibility of in situ treatments. Injection through screened wells is not applicable for this site because it is only effective in high permeability soils. In tight soils where contaminants may have diffused into the low permeability matrix, the rate of back-diffusion into the higher permeability zones—where mass can be removed or destroyed more readily—limits the speed of cleanup. Environmental fracturing technologies are used to decrease the distance that back-diffusing contaminants need to travel (and thus decrease the back-diffusion time) by either creating new high permeability zones, or connecting previously unconnected high permeability zones. Environmental fracturing can utilize water or slurry to introduce fractures (e.g, new high permeability zones), referred to as hydraulic fracturing, or utilize air or gas to introduce fractures, referred to as pneumatic fracturing. Both fracturing technologies are discussed in this section. Electrokinetic distribution does not create new pathways, but instead relies on the introduction of electrical charges to induce the movement of ions through soils.

2.6.6.3.1 Environmental Hydraulic Fracturing

Hydraulic Fracturing is a technology in which pressurized water or a slurry of chemical reagents is injected into the subsurface to increase permeability. It can be conducted in both the vadose zone and below the water table. The fracturing process begins with the injection of water or a slurry of chemical reagents into a sealed borehole under high pressure that exceeds the soil entry pressure and creates a fracture along a plane. The typical propagation radius of a fracture plane in silt and clay is 40 to 50 feet. In situ treatment reagents are then introduced into the fracture, and the reagents diffuse into the soil along the fracture.

<u>Effectiveness</u> – Hydraulic fracturing is a supporting technology in combination with other in situ treatment technologies. It can be an effective technology to enhance the distribution of amendments during an in situ treatment application, such as ISCO and bioremediation. Once in the fractures, the amendments will permeate into the microporous structure of the low permeability matrices to contact and destroy the VOC contaminants. Fracturing and injection would be performed at different depths in one borehole, and in multiple boreholes across the site. However, it should be noted that the direction of the fractures cannot be completely controlled, so there is the risk that fractures may not provide adequate distribution of the amendment, and some contamination would remain untreated. Due to the introduction of liquids during the fracturing, hydraulic fracturing will be more effective than pneumatic fracturing for technologies where high moisture content is desirable (ISCO, bioremediation, in-situ chemical reduction [ISCR]).

<u>Implementability</u> – This technology can be properly implemented by experienced vendors. Generally, fracturing contractors avoid damaging buildings by not fracturing in the first ten feet bgs. Implementation at shallower depths would require demolishing the buildings within the fracture propagation zone.

<u>Relative Cost</u> – This process option would involve medium capital costs and no operation and maintenance costs.

<u>Conclusion</u> – Hydraulic fracturing is retained for further evaluation in combination with other in situ remedial technologies.

2.6.6.3.2 Environmental Pneumatic Fracturing

Pneumatic Fracturing involves injecting air or an inert gas (usually nitrogen) into the subsurface at pressures exceeding the natural in situ stresses, and at flow volumes exceeding the natural permeability of the formation. This action results in the propagation of a network of fractures outward from the injection point, and thus an increase in net porosity. Fracture propagation distances of 20 to 40 feet are typically observed in silt and clay geology. For maximum control, the fracturing is carried out in narrow depth intervals to concentrate the effect of the pressure pulse and to help minimize the formation or propagation of vertical fractures. A significant advantage of using an inert gas as an injection fluid in pneumatic fracturing is that liquids are not introduced into the formation, as these may tend to remobilize contaminants. Pneumatic fracturing can provide beneficial aeration if air is used during injection and causes less permanent ground deformation, which is especially desirable when fracturing in the vicinity of structures and utilities.

<u>Effectiveness</u> – This process option is a supporting technology used in combination with other in situ treatment technologies. It can be effective in enhancing contaminant removal when used with SVE or distribution of reagents when used with ISCO or in situ chemical reduction technology. Once in the

fractures, the reagents will permeate into the microporous structure of the low permeability matrices to contact and destroy the VOC contaminants. Fracturing and injection would be performed at different depths in one borehole, and in multiple boreholes across the site. However, it should be noted that the direction of the fractures cannot be completely controlled, so there is the risk that fractures may not spread to the full extent of the treatment zone, and some contamination would remain untreated. Compared to hydraulic fracturing, pneumatic fracturing will be more effective for technologies where low moisture content is desirable (SVE), and less effective for technologies where high moisture is desirable (ISCO and bioremediation).

Implementability – This technology can be properly implemented by experienced vendors. Generally, fracturing contractors avoid damaging buildings by not fracturing in the first ten feet bgs. Implementation at shallower depths would require demolishing the buildings within the fracture propagation zone.

Relative Cost – This process option would involve medium capital costs and no operation and maintenance costs.

Conclusion – Pneumatic fracturing is retained for further evaluation in combination with other in situ remedial technologies.

2.6.6.3.3 Electrokinetics

Electrokinetics involves the application of a DC electric field to saturated soils via an anode and a cathode. Negatively charged ions move to the positively charged anode, and positively charged ions move to the negatively charged cathode in a process termed electro-migration. As long as a conductive medium is connecting the anode and cathode to complete the circuit, charged ions will move through the medium regardless of permeability or porosity—soil characteristics that are limiting factors with other amendment distribution techniques. Water is the principal conductive medium. Many amendments for in situ treatment are charged ions in solution; electrokinetics would therefore be a technique to distribute charged ion amendments through the low permeability soils at the site.

Effectiveness – This process option is a supporting technology used in combination with other in situ treatment technologies. The major limitation expected at Cidra is that site soils have a moisture content of approximately 30% – damp but not saturated. Therefore, the circuit may not be complete in all or part of the target treatment zone and amendments may not be distributed as uniformly as desired.

Implementability – As of the writing of this FS, this technology is not widely applied. It may be difficult to identify experienced vendors to implement electrokinetics.

Relative Cost – This process option would involve medium capital costs and operation and maintenance costs.

Conclusion – Electrokinetics is retained for further evaluation in combination with other in situ remedial technologies.

2.6.6.4 In Situ Chemical Oxidation

ISCO involves the injection of strong chemical oxidants (e.g., hydrogen peroxide, [H_2O_2], persulfate [$S_2O_8^{2-}$], potassium permanganate [$KMnO_4^-$] and/or ozone [O_3]) into the contaminated subsurface to destroy organic contaminants and produce non-toxic compounds that are more stable, less mobile, and/or inert. Chemical oxidation of chlorinated VOCs typically results in non-toxic end products such as water, carbon dioxide, and dilute hydrochloric acid. Oxidants vary by how long they last in the subsurface and whether or not they require activation (for example with heat or pH).

Factors that must be considered when implementing ISCO include site-specific geology, the ability to distribute the oxidants into the contaminated media, the soil oxidant demand, and the soil moisture content in the vadose zone. ISCO is a non-selective oxidation process. The oxidants would react with the contaminants and naturally occurring compounds in soil, including organic compounds and select metals. Thus an excess amount of oxidants would be required to satisfy the oxidant demand of the native soil.

For chlorinated solvents, the major factor for effectiveness of ISCO is distribution of the oxidant to achieve direct contact between the oxidants and the contaminants. In general, ISCO requires the treatment zone to be saturated.

<u>Effectiveness</u> – The effectiveness of using ISCO treatment at this site has uncertainties because the contamination is located in a heterogeneous low permeability soil in the vadose zone. ISCO reactions take place in the aqueous phase. Site soils have a moisture content of approximately 30% – damp but not saturated. Therefore, using ISCO will require an implementation technique that saturates the soil and ensures contact of the oxidant with the contaminants.

<u>Implementability</u> – Achieving good distribution of the oxidant throughout the unsaturated, low-permeability clay of the treatment zone would be difficult. Injection would have a very limited range of influence in this geology and not be cost effective. Even with the use of environmental fracturing technologies, the oxidants would be in primary or secondary fractures that would still require the oxidant to diffuse up and out of the clay matrix. In situ soil mixing is a technique that could mechanically mix the amendment and water into the clay and create the contact and saturation needed for successful remediation. Space limitations at the site for soil mixing equipment may affect implementability.

<u>Relative Cost</u> – ISCO involves medium to high capital costs and low O&M costs.

<u>Conclusion</u> – ISCO will be retained for further evaluation.

2.6.6.5 In Situ Bioremediation

In situ bioremediation can be conducted for the site-related contaminants using enhanced anaerobic bioremediation (EAB) technology and aerobic cometabolic bioremediation (ACB) technology.

EAB is a technology that can remediate chlorinated VOC contamination in soil and groundwater through biological mechanisms. EAB involves the injection of organic substrate (electron donor) solution into the subsurface to stimulate the growth of native microorganisms to detoxify chlorinated VOC contaminants under anaerobic conditions. The predominant pathway for anaerobic biological degradation of chlorinated VOCs is via reductive dechlorination as discussed under Section 2.5.3 MNA. The biological reactions occur in the aqueous phase. The addition of an electron donor as an energy source for indigenous microorganisms would stimulate the development of reduced aqueous environments that are conducive to biologically-mediated dechlorination reactions (i.e., methanogenic conditions), and fuel the dechlorination process itself. Additionally, the reducing conditions can lead to the formation of reduced iron minerals in the subsurface that induce abiotic degradation pathways for VOCs (Adamson et al. 2011). The quantity of electron donor injected into the subsurface is usually designed conservatively to ensure that it would not be the limiting factor for EAB treatment.

For complete reductive dechlorination, the presence of a strain of the bacterium (DHC, is required. At some sites, lack of DHC results in dechlorination progress stalling at cis-1,2-DCE. To achieve complete dechlorination at such sites, DHC bacteria can be injected after the establishment of anaerobic conditions in the aquifer. This is referred to as bioaugmentation.

<u>Effectiveness</u> – At both IDC and Ramallo, anaerobic degradation products of PCE were detected, indicating that biodegradation has occurred and there was sufficient moisture in the subsurface to maintain anaerobic biodegradation. Given the probable flow of contaminants through the lineations in the clayey soils, no large pools of DNAPL are expected that would reduce effectiveness of EAB. Vinyl chloride was detected in some samples in both these areas, indicating the presence of DHC. To sustain effective treatment at the site, a sufficient concentration of the electron donor needs to be distributed into the treatment zone, sufficient moisture must be present to sustain a biological community, and anaerobic conditions must be maintained. For this site, the target treatment zone is in clay and silty clay in the vadose zone. Given the low permeability, anaerobic conditions should be relatively easy to maintain since oxygen does not easily permeate silt and clay.

As indicated above, an important factor for effective EAB treatment is adequate distribution of electron donor. Establishing a high biomass with active dechlorinators can often self-sustain for several years, especially if long-lived amendments are used and any contaminants diffused out of low permeable zones would also be treated. The biomass would be present mainly as a biofilm on the soil particles; biofilms will be more resilient to the wetting and drying cycles that would be expected in a vadose zone receiving occasional rainwater infiltration. For this site where the vadose zone soil consists of low permeable clay and silt, electron donor cannot be effectively distributed through injection alone. Environmental fracturing could be used as a delivery mechanism to enhance electron donor distribution.

<u>Implementability</u> – Equipment and experienced vendors for EAB treatment are commercially available, though they may have to travel from the continental US. EAB can be implemented in a vadose zone by continuously or intermittently injecting either aqueous or gaseous electron donor solution into the target treatment area (after environmental fracturing). The quantity of an aqueous solution injection would need to be managed to minimize the potential impact to groundwater. Due to space limitations, all or part of the buildings on the treatment zone footprint may need to be demolished.

Relative Cost – This technology would require medium capital cost and medium O&M costs over several years since multiple rounds of amendment injections would be necessary.

Conclusion – EAB is retained for further consideration.

2.6.6.6 In Situ Chemical Reduction

ISCR is a process using a reductant to chemically reduce the contaminants to non-hazardous compounds. The most widely used reductant for reducing chlorinated hydrocarbons is zero-valent iron (ZVI). ZVI has been applied in several ways to remediate contaminants: in a permeable reactive barrier; in nano scale through injection; in micro-scale through injection or with hydraulic fracturing. Recently, ZVI has also been combined with organic carbon amendments for in-situ remediation; for example, emulsified ZVI (EZVI) is a proprietary product developed by National Aeronautics and Space Administration containing emulsified oil coated ZVI. EHC is a proprietary product developed containing ZVI and controlled-release carbon in a solid form.

Effectiveness – Achieving uniform delivery of the reductant and adequate contact of reductant with contaminants would be critical for effective treatment. Since reductants are particles and not aqueous solutions or gases, limited diffusion into the clay would occur. However, the reductants are long lasting in the subsurface, providing treatment when contaminants either back-diffused out of the clay or leached into the zone with infiltrating rainwater.

Implementability – Achieving adequate distribution of the ISCR amendment is the key implementation hurdle for in-situ chemical reduction. Environmental fracturing would be necessary to distribute the particulate reductant into the low-permeability clay at the site. Equipment and experienced vendors are available, though they may have to come to the site from the States.

Cost – This technology would involve high capital cost. Depending on the delivery technology and the depth required to be achieved, the O&M cost could be minimal, mainly from a monitoring cost standpoint.

Conclusion – ISCR is retained for further consideration.

2.6.7 Disposal

Disposal response actions for soil involve the disposal of excavated soil in an offsite facility permitted for the specific waste type, or backfill on site if treated to regulatory limits.

2.6.7.1 Offsite Disposal at Non-Hazardous Waste (RCRA Subtitle D) Landfill

This option involves disposing the contaminated soil at an offsite non-hazardous waste (RCRA Subtitle D) disposal facility. Offsite landfills are commercially owned, permitted facilities that minimize potential environmental impacts of disposal waste. Landfilling is considered a non-treatment alternative and is considered less acceptable than treatment alternatives by CERCLA. Soil that is not toxicity characteristic per the Toxicity Characteristic Leaching Procedure (TCLP) could be disposed in a subtitle D landfill. However, the final determination would be based on the evaluation of a suite of parameters by the landfill.

Effectiveness: – Landfill disposal is effective in preventing direct contact and in reducing mobility of contaminants. The volume and toxicity of the waste is not reduced.

Implementability: – This technology is technically implementable.

Relative Cost: – This process involves moderate capital and no O&M costs.

Conclusion: –Offsite disposal is retained for disposal of excavated soils, investigation derived wastes and miscellaneous wastes that pass TCLP.

2.6.7.2 Offsite Disposal at a Hazardous Waste (RCRA Subtitle C) Landfill

Offsite disposal would be implemented in conjunction with the removal action for contaminated soil. Offsite disposal is considered a non-treatment alternative and is considered less acceptable than treatment alternatives by CERCLA. If the contaminated soil exceeds the TCLP criteria, it would be disposed in a RCRA Subtitle C landfill, or require treatment on-site or at a hazardous treatment facility to meet the Universal Treatment Standards (UTS) prior to disposal. Offsite landfills are commercially owned, permitted facilities that minimize potential environmental impacts of disposed waste.

Effectiveness: Landfill disposal is effective in preventing direct contact and in reducing mobility of contaminants. The volume and toxicity of the waste is not reduced. If treatment is conducted to meet the LDR requirements, toxicity and mobility of the treated soil would be reduced.

Implementability: This process option needs to be implemented with a removal action for contaminated soil. The difficulty of implementation is compounded by the fact that no RCRA Subtitle C landfills exist in Puerto Rico.

Relative Cost: RCRA Subtitle C landfills that accept contaminated soils are available in the continental United States but not in Puerto Rico. Thus this process would involve high shipping costs. There are no O&M costs, and capital costs are relatively moderate.

Conclusion: Offsite disposal is retained for disposal of excavated material, investigation derived wastes and miscellaneous wastes that fail TCLP.

2.7 Identification and Screening of Remedial Technologies and Process Options for Groundwater

For each GRA, technologies and process options potentially capable to address site contamination in the saprolite and bedrock aquifers are identified and screened in this section. Representative remedial technologies and process options that are retained will be used to develop remedial action alternatives in Section 3, either alone or in combination with other technologies. Table 2-6 summarizes the technology screening for the saprolite and bedrock aquifer.

As stated in Section 2.5, the technology screening approach is based upon the procedures outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988), and considers three criteria: effectiveness, implementability, and relative cost.

2.7.1 No Action

Under the No Action response action, no remedial actions will be conducted to reduce exposure to the contaminated soil.

Effectiveness – The effectiveness of No Action will be low because the RAOs will not be met.

Implementability – No Action is easy to implement from a technical perspective, and no significant administrative difficulties are expected.

Relative Cost – There is no cost for this response action.

Conclusion – No Action is retained as a baseline for comparison to other alternatives, as required by the NCP.

2.7.2 Institutional/Engineering Controls

Institutional/Engineering Controls do not reduce the T/M/V of contamination, but can be implemented to reduce the probability of exposure to contaminants. Institutional controls consist of administrative actions which control use of the site (e.g., deed restriction), and community educational programs to increase awareness about contamination on the site. Engineering controls consist of installation of engineering systems to prevent or reduce the exposure to site contaminants, such as public water supply management. Institutional/Engineering Controls generally would require long-term monitoring of contaminant concentrations. Typical Institutional/Engineering Controls are discussed below.

2.7.2.1 Land Use Controls

Land use controls are local administrative actions that are used to prevent certain types of uses for properties where exposure pathways to contaminants may be created as a result of those uses. Land use controls may be used to require the installation of a vapor mitigation system, prevent installation of septic systems, or removal of asphalt or concrete pavements within the contamination plume area. They may also include well drilling restrictions. PREQB has the administrative authority to prevent the installation of drinking water wells in the contaminated areas. Drilling of wells for irrigation could also be restricted. Land use controls are generally administrated by the local government.

Effectiveness - Land use controls could effectively restrict or eliminate exposure to contaminated groundwater, thereby reducing human health risks posed by the plume. The effectiveness of land use controls would depend on proper enforcement. Land use controls would not reduce the migration and environmental impact of the contaminated groundwater in any of the contaminant areas.

Implementability - Land use controls may not be easy to implement. Their implementability would highly depend on the local government and its enforcement system.

Relative Cost - The implementation cost is low. Some administrative, long-term inspection and periodic assessment costs would be required.

Conclusion - Deed Restrictions are retained for further evaluation.

2.7.2.2 Community Awareness

Community awareness involves information and education programs to enhance awareness of potential hazards, available technologies that are capable to address the contamination, and the remediation progress to the local community.

Effectiveness - Educational programs would protect human health by bringing awareness of the contamination conditions and would enhance the implementation of deed restrictions within the contaminated aquifer.

Implementability - This option would be implementable.

Relative Cost - Community awareness would have low capital and operational costs.

Conclusion - Community awareness is retained.

2.7.2.3 Monitoring

Monitoring includes periodic sampling and analysis of groundwater. The monitoring program provides an indication of the progress of remedial activities and contaminant migration after active treatment. Data collected by the monitoring program would be used in five-year reviews.

Effectiveness - Monitoring alone would not be effective in reducing contamination levels. It would not alter the risk to human health or the environment. Monitoring would be effective in providing information on site conditions to decision makers for the contaminated aquifers.

Implementability - Groundwater monitoring is a proven and reliable process, and could be easily implemented. A comprehensive monitoring network would need to be installed for the monitoring program.

Relative Cost - Monitoring would involve medium capital cost if the monitoring network would need to be established by installation of wells and medium O&M costs.

Conclusion - Monitoring is retained for both the saprolite and bedrock aquifers.

2.7.3 Monitored Natural Attenuation

MNA refers to the remedial action that relies on naturally occurring attenuation processes to decrease contaminant concentrations and to achieve site-specific RAOs within a reasonable time frame. Natural attenuation processes that reduce contaminant concentrations in groundwater include destructive (biodegradation and chemical reactions with other subsurface constituents) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption).

Biodegradation is typically the most significant destructive attenuation mechanism. Chlorinated solvents, such as PCE, attenuate predominantly by reductive dechlorination under anaerobic conditions. The primary reductive dechlorination pathway of PCE to ethene is given below:

PCE → TCE → cis-1,2-DCE → Vinyl Chloride → Ethene

In the reductive dechlorination process, PCE acts as an electron acceptor and it requires an adequate supply of electron donors (usually measured by total organic carbon) to completely degrade PCE. The existence of other electron acceptors, such as oxygen, nitrate/nitrite, ferric iron, or sulfate can compete for electron donors and potentially inhibit the dechlorination process. Additionally, the presence of a genus of bacteria DHC is found to be necessary for complete dechlorination to ethene. In the lack of DHC, dechlorination process would stall at cis-1,2-DCE. It should be noted that TCE, cis-1,2-DCE, and vinyl chloride can attenuate under aerobic conditions.

Biodegradation of TCE, DCE, and vinyl chloride can also occur under aerobic conditions via a cometabolic degradation process. Cometabolism occurs in conjunction with the metabolism of a primary substrate, which the microorganisms use for carbon and/or energy. The enzyme that transforms the primary substrate also fortuitously degrades the contaminants. TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE and vinyl chloride have been shown to be susceptible to cometabolic oxidation under aerobic conditions (Alvarez-Cohen and Speitel 2001).

The most studied TCE-cometabolizing microbes are methanotrophic bacteria, which use methane as their sole source of carbon and energy. Methanotrophic bacteria produce an enzyme called methane monooxygenases (MMO), which catalyzes the oxidation of methane to methanol and is capable of cometabolic TCE oxidation. Enzyme activity probes have shown that specific oxygenases can yield quantifiable fluorescent products when the enzyme is actively functioning. The enzyme activity probe technology provides a direct line of evidence for active cometabolic degradation. Bacteria (e.g., methanotrophs) capable of aerobic cometabolic degradation of TCE are ubiquitous. The key factors that could limit intrinsic aerobic cometabolic degradation are oxygen and the presence of primary substrates that can induce the appropriate enzymes.

To evaluate the occurrence of intrinsic biodegradation, biogeochemistry data are often analyzed, including distribution of electron acceptors and its reduced form (e.g., nitrate/nitrite, sulfate/sulfide, ferrous iron/ferric iron concentrations), PCE degradation intermediates and products, and the contaminant distribution and time trends. It is possible to determine whether active reductive dechlorination of the chlorinated compounds has been occurring, while it is much more difficult to evaluate abiotic or aerobic cometabolic degradation of TCE due to lack of intermediate products.

<u>Effectiveness</u> – MNA is effective where natural attenuation mechanisms have been shown to be able to meet the RAOs within a reasonable timeframe. In both the saprolite and the bedrock, detectable levels of methane were observed in the plume and groundwater is anaerobic. While some degree of reductive dechlorination has or is occurring—as demonstrated by the detection of TCE and cis-1,2-DCE—the lack of detected vinyl chloride in most of the wells and the low total organic carbon (<2 milligrams per liter [mg/L]) in the plume indicate that either DHC may not be present, and/or there may be insufficient organic carbon to sustain the dechlorinating microbes. Cometabolic degradation is not effective for PCE. No evidence has been collected to indicate that abiotic degradation has been occurring. The conclusion is that there is insufficient evidence to demonstrate that MNA would effectively meet RAOs within a reasonable timeframe.

Implementability – MNA is implementable. Materials and services necessary to model and monitor the natural attenuation are readily available. Institutional/engineering controls would be required to minimize human exposure to contaminants.

Relative Cost – MNA and associated modeling involve low capital costs and medium O&M costs for long-term monitoring, and periodic reassessment costs.

Conclusion – MNA will not be retained because it is not anticipated to be effective at meeting the RAOs within a reasonable timeframe.

2.7.4 Containment

Low-permeability barrier walls could be installed downgradient from source areas or plumes to control contaminant migration. Containment technologies would only be effective in areas of the site where the contamination is at shallow depths on top of a continuous, non-leaky confining clay layer.

2.7.4.1 Slurry Walls

Slurry walls are constructed by making low-permeability slurry, typically consisting of either a soil-bentonite or cement-bentonite mixture, into an excavated trench. Excavation can be completed using a long-arm excavator and a clam shovel to achieve the required depth. Slurry is pumped into the hole during the course of excavation to keep the sidewalls from collapsing. This technology is generally used for an overburden aquifer, not for a bedrock aquifer.

Effectiveness - Slurry walls would not be effective for this site because there is no continuous non-leaking confining unit underneath the contamination source area; contaminants have already migrated into the bedrock.

Implementability - Construction materials and services would be readily available. Typical slurry wall applications reach installation depths of about 30 to 40 feet bgs, based upon practical limitations associated with excavator trenching. Slurry walls can be installed to depths of 100 feet bgs using a clam shovel at a higher unit cost. At this site, the groundwater contamination is in the saprolite and bedrock aquifers. Both are greater than 100 feet below ground surface. Slurry walls would not be implementable at this site due to the depth of the saprolite layer and existence of contamination in the bedrock.

Relative Cost - Slurry walls would involve high capital cost.

Conclusion - Slurry walls are not retained for further consideration in either aquifer due to a lack of effectiveness and implementability.

2.7.4.2 Sheet Pile Barriers

Sheet pile barriers are constructed by driving or vibrating sections of steel sheet piling into the ground. Each sheet pile section is interlocked at its edges, and the seams are often grouted to prevent leakage. Upon the completion of remedial activities, the sheet piles can be vibrated out of the ground, disassembled, and removed from the site, provided that the sheeting and joints are still of good structural integrity at the time of removal. Otherwise, the sheets are cut off below the ground surface, and the walls continue to influence groundwater flow patterns on a localized scale.

Effectiveness - Sheet pile walls are effective at providing hydraulic source control if the aquifer is shallow and the contamination source is located on top of a confining unit. However, at this site, the aquifer is beyond the reach of sheet piles and the contaminants have already migrated into the fractured bedrock. Installing sheet pile walls might enhance the vertical gradient, thus enhancing the contaminant migration into the bedrock aquifer, which is highly undesirable. Sheet pile walls would not be effective for this site.

Implementability - Sheet piles have been widely used in the heavy construction industry, particularly for groundwater control and slope stability. Construction materials and services would be readily available. Typical sheet pile wall applications reach installation depths of about 80 feet bgs, based upon subsurface conditions and practical limitations associated with installation. Sheet pile walls would not be implementable because the aquifer is greater than 80 feet deep.

Relative Cost -Sheet pile walls would involve high capital cost.

Conclusion - Sheet pile walls are not retained for further consideration due to lack of effectiveness and implementability.

2.7.5 Groundwater Extraction

Extraction technologies involve placing extraction wells or trenches to intercept the flow of contaminated groundwater and hydraulically prevent contaminants from migrating downgradient. The extracted groundwater is typically treated ex-situ and disposed of on-site or off-site. Representative process options are described below.

2.7.5.1 Extraction Wells

This process option involves the installation of groundwater extraction wells within areas of contamination to provide hydraulic control and capture contaminants. They are effective when combined with other treatment and discharge technologies. Groundwater extraction can be applied to both the saprolite and bedrock aquifers.

Effectiveness - Groundwater extraction is effective in providing hydraulic control and contaminant removal at sites where the soil is moderate to highly permeable, the hydrogeology is well understood, and the pumping rate necessary to maintain hydraulic control is sustainable. It is generally not effective for contaminant removal where the contaminants are distributed in heterogeneous low permeability materials such as silt and/or clay.

The saprolite is comprised of both weathered bedrock and clay or silty clay particles from the overburden. The saprolite is considered to be fractured and porous; no consolidated, low-permeability layers are believed to be present where diffusion could have created a reservoir of sorbed contamination (except the overlying soil, which is considered separately herein). Back-diffusion from the porous particles should occur relatively quickly. The saprolite is a semi-confined aquifer and will be easier to pump than an unconfined aquifer.

Contamination was potentially drawn into bedrock from the saprolite initially by pumping in the supply wells. When the supply wells were shut off, contamination spread in the bedding planes along strike and downdip along with the natural (unpumped) flow of groundwater. Therefore in theory, the contaminated parts of the bedrock aquifer are hydraulically connected to the bedding planes where the supply wells are screened. Extracting water from these same bedding planes (for example, using the supply wells as extraction wells) would extract the contamination. However, it is unknown if contamination has entered other, unconnected bedding planes in the bedrock in the time period after the supply wells were shut off. It is also unknown to what extent contamination has diffused out of the bedding planes and into the bedrock matrix. If this is the case, groundwater extraction would be less effective at meeting the RAOs site-wide within a reasonable timeframe.

<u>Implementability</u> - Installation of groundwater extraction wells would be technically implementable in the saprolite. Due to the complexity of bedding planes and fractures in the bedrock, it would be difficult to predict with certainty where extraction wells should be screened in order to extract contamination. Necessary equipment and materials would be readily available.

<u>Relative Cost</u> - Groundwater extraction would involve medium to high capital costs due to the depth of drilling; costs would be higher for the bedrock aquifer than for the saprolite. Medium cost for O&M due to the prolonged period of operation would be required.

<u>Conclusion</u> - Extraction wells are retained for the saprolite and the bedrock.

2.7.5.2 Extraction Trenches

This technology involves construction of a trench perpendicular to the direction of groundwater flow to intercept and prevent downgradient migration of a contaminant plume. A bio-polymer slurry is used temporarily to support the sidewalls of the trench, preventing collapse of the trench sidewalls. The trench is typically backfilled with material of higher permeability than the native aquifer (e.g., gravel) to create a zone of preferential flow, and perforated piping or well screens are typically installed in the trench to collect the intercepted groundwater. After the piping and backfill have been installed, an additive is pumped into the trench to break down the slurry to simple sugars and water, thus re-establishing hydraulic connection to the aquifer. Extracted groundwater is then treated as necessary to meet discharge requirements. Extraction trenches are generally used for contamination at shallow depth. One-pass trenching can excavate and backfill with sand as the same time.

<u>Effectiveness</u> - Extraction trenches are effective in capturing groundwater to provide hydraulic control. To meet the RAOs, sufficient contaminant mass needs to be captured such that the PRGs are met within a reasonable timeframe. Aquifers where matrix diffusion and slow desorption kinetics occur can be problematic, since groundwater will be continually fed by back-diffusion and desorption from the soils.

<u>Implementability</u> - The equipment and materials would be readily available. However, an extraction trench is typically installed at depths less than 30 feet bgs due to trenching equipment limitations. The contaminated aquifers are at depths exceeding 100 feet; thus extraction trenches are not implementable.

<u>Relative Cost -</u> Extraction trenches would involve medium capital cost. Medium cost for O&M due to the prolonged period of operation would be required.

Conclusion - This technology is not retained for further evaluation in either aquifer due to the lack of implementability.

2.7.6 Ex-Situ Treatment Technology

If groundwater extraction, air sparging, or in-situ thermal remediation is selected as a remediation option, an ex-situ treatment system would be required to remove contaminants from the groundwater or extracted vapor before discharge. Several ex-situ treatment technologies were identified as potentially applicable at the site.

2.7.6.1 Air Stripping

Air stripping is a physical mass transfer process that uses clean air to remove dissolved VOCs from water by increasing the surface area of the groundwater exposed to air. Commonly used systems include the countercurrent packed column, multiple-chamber fine-bubble aeration systems, venturi systems, and low profile sieve tray air strippers. In a countercurrent packed column, contaminated groundwater is sprayed through nozzles at the top of the column, flowing downward through packing materials. In a low profile sieve tray air stripper, contaminated groundwater flows across the surface of a series of perforated trays. In both systems, clean air is forced into the system by a blower in a direction opposite to groundwater flow (e.g., from the bottom, flowing upward). In a multiple chamber fine bubble aeration system, contaminated groundwater flows through aeration tank chambers, and air is introduced at the bottom of each chamber through diffusers forming thousands of fine bubbles. As the fine air bubbles travel upward through the water, mass transfer occurs at the bubble/water interface. System efficiency increases with decreasing bubble diameters.

In general, the water stream exiting the air stripper can be discharged to surface water or groundwater. The vapor effluent would likely require treatment (e.g., catalytic oxidation) before discharge to the atmosphere.

Effectiveness - Air stripping would be effective in removing volatile contaminants from water. Air stripping is proven to successfully remove PCE and its byproducts from water, because of high Henry's law constants. Contaminants extracted from the treatment areas could be effectively treated.

Implementability - Air stripping would be implementable. Vendors and equipment would be readily available to provide air strippers for groundwater VOC removal. It would need to be implemented with groundwater extraction and discharge technologies. Air stripping would typically not be used in the water treatment system implemented for in-situ thermal remediation.

Relative Cost - Air stripping would have low capital and low O&M costs.

Conclusion - Air stripping is retained for further evaluation.

2.7.6.2 Potassium Permanganate Oxidation

When vinyl chloride and cis-1,2-DCE are present in the treatment system off-gas, potassium permanganate can be used for both neutralization and oxidation. Typically, an ion exchange resin (zeolite) is impregnated with a solution of potassium permanganate. Potassium permanganate will react to form three compounds: potassium hydroxide; manganese tetraoxide; and manganese dioxide. The manganese tetraoxide will oxidize vinyl chloride into potassium chloride and carbon dioxide. The potassium chloride will remain in the pore structure of the substrate that contains the hydrated potassium permanganate.

Effectiveness - Potassium permanganate oxidation would be effective in removing contaminants including cis-1,2-DCE and vinyl chloride from the system off-gas.

Implementability - Potassium permanganate oxidation systems are implementable and a proven technology. The equipment and materials would be readily available through vendors. It could be implemented with groundwater extraction or in-situ thermal remediation technologies.

Relative cost - This technology would involve medium capital and medium O&M costs.

Conclusion - Potassium permanganate oxidation is retained for further evaluation.

2.7.6.3 Granular Activated Carbon (GAC) Adsorption

Extracted groundwater or off-gas can be pumped through vessel(s) containing GAC to which contaminants would be adsorbed and removed. When the concentration of contaminants in the effluent exceeds a pre-established value (breakthrough), the GAC is removed for regeneration or disposal.

Effectiveness - This process option would reduce concentrations of contaminants in groundwater or in the off-gas. The technology is often used to polish water discharges from other remedial technologies to attain regulatory compliance. Carbon adsorption would be effective in removing contaminants with moderate or high organic carbon partition coefficients (K_{oc}) from groundwater. The process is not effective for removing vinyl chloride and cis-1,2-DCE, which do not effectively adsorb to carbon. In this situation, potassium permanganate would be used to absorb vinyl chloride and cis-1,2-DCE. GAC may be susceptible to biological and inorganic fouling.

Implementability - Activated carbon adsorption is implementable. The equipment and materials are readily available. Logistic and economic disadvantages arise from the need to transport and decontaminate spent carbon. Costs are high if it is used as the primary treatment on waste streams with high contaminant concentration levels. It would need to be combined with groundwater extraction and discharge technologies. O&M requirements include monitoring of influent and effluent streams, regeneration and replacement of carbon, and backwashing.

Relative Cost - This technology would involve medium capital and O&M costs.

Conclusion - GAC is retained for further evaluation.

2.7.6.4 Ultraviolet/Oxidation

This process option is used when destruction of contaminants is preferred or when contaminants cannot be removed with GAC or air stripping. Extracted groundwater would be pumped through a reactor where it is combined with ozone and/or hydrogen peroxide and irradiated with ultraviolet (UV) light. Organic contaminants are destroyed as a result of the synergistic action of the oxidant with

UV light. The system may require off-gas treatment to destroy unreacted ozone and volatilized contaminants.

Effectiveness - UV/Oxidation would be an effective method to treat chlorinated VOC contaminants, including cis-1,2-DCE and vinyl chloride, in groundwater extracted from the contaminant plume; however high turbidity in the water can cause interference and reduce effectiveness.

Implementability - This technology is implementable. Vendors and equipment for UV/oxidation are readily available. It can be implemented with groundwater extraction and discharge technologies. Minor administrative difficulties are anticipated for implementation of a UV oxidation system as it may require permit for discharge of unreacted ozone and volatilized VOCs. Alternatively, treatment of off-gas may be required.

Relative Cost - This technology would involve high capital and O&M costs. A UV/oxidation system is generally more costly than an equivalently-sized GAC unit. It would also require more electricity to operate.

Conclusion - UV/Oxidation is retained for further evaluation.

2.7.6.5 Biological Treatment

Ex-situ biological treatment techniques are directed toward stimulating microorganisms to grow and use contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing a combination of oxygen and nutrients, and controlling the temperature and pH. Microorganisms adapted for degradation of specific contaminants are applied to enhance the process. In a biological reactor, contaminated groundwater is placed in contact with microorganisms. In suspended growth systems, contaminated groundwater is circulated in an aeration basin where a microbial population aerobically degrades the contaminants. In attached systems, such as rotating biological contactors and trickling filters, microorganisms are established on a fixed surface and biologically degrade contaminants as contaminated groundwater passes over the surface. The reactions require initial seeding to more quickly establish a microbe population inside the reactor.

Effectiveness - Treatability studies must be performed prior to treatment to determine if contaminants are biodegradable and to estimate the rate of biodegradation. Low temperatures significantly decrease the rate of biodegradation, resulting in longer cleanup times or increased cost for heating. Given the potentially long residence times that would be needed to meet Puerto Rico water quality standards, biological treatment is likely not effective at the site.

Implementability - The space requirements and complexity of the system would make this technology difficult to implement. Vendors and equipment are readily available. Metals removal may be required prior to treatment in the bioreactor.

Relative costs - Costs for implementing biological treatment in a reactor can be highly variable and depend on the type of contaminants and the concentrations in the influent stream. Other costs to consider include clarification, settling, and the potential need for liquid-phase activated carbon as a secondary polish step. O&M costs for this system will be negligible.

Conclusion - Biological treatment is not retained for further evaluation.

2.7.7 In-Situ Treatment Technology

Several in-situ treatment technologies are identified and discussed below. In-situ technologies can often achieve RAOs within a shorter period of time compared to the groundwater extraction technologies, especially where a high degree of matrix diffusion or sorption has occurred.

2.7.7.1 In-situ Thermal Remediation

In-situ thermal remediation technologies transfer heat into the aquifer, causing groundwater and the contaminants (especially VOCs) to vaporize or evaporate, increasing the rate of diffusion out of the soils and into groundwater, increasing the solubility of contaminants, and potentially enhancing abiotic degradation or even biological degradation of contaminants. Thermal treatment is especially effective at treating low permeability aquifers. Permeability of subsurface soil may vary over many orders of magnitude in a natural geological setting. However, thermal conductivities range over less than one order of magnitude, which allows much more uniform heating and treatment within a contaminated zone compared to treatments that rely on the delivery of reagents.

Heat can be delivered by direct conduction of heat away from heaters in wells (thermal conductive heating); by passing electrical currents through the subsurface (electrical resistivity heating [ERH]); steam injection; or by propagating radio frequency energy into the soil from source transmitters (radio frequency heating). Contaminants transferred into the vapor phase rise to the unsaturated zone where they are captured by vacuum extraction and then treated above ground.

Effectiveness - In-situ thermal remediation has been successfully applied to desorb and volatilize contamination sources in the geology similar to this site: fractured/porous bedrock and competent bedrock. Due to the evaporation of groundwater, water levels within the treatment zone decrease, thus creating a hydraulic gradient toward the treatment zone and acting as a hydraulic control. If too much unheated water enters the treatment zone from upgradient, it can create a significant heat sink, which decreases the efficiency of the technology.

A concern of applying in-situ thermal treatment in both the saprolite and the bedrock is the potential uncontrolled migration of vapor or dissolved contaminants. Controlling the migration of contaminant vapor in fractured bedrock systems where the pathways may follow the orientation of fractures could be problematic.

Residual heat following cessation of heating would also be capable of stimulating accelerated biodegradation of remaining low-concentration contaminants.

Implementability - The technology would require a significant, reliable source of electrical power to heat the aquifer. Effective vapor capture would be difficult to implement at the site because the saprolite is a confined aquifer. The vadose zone (where the vapor extraction wells would be screened) is a low permeability clay, and therefore the radius of influence of the vapor extraction wells would be prohibitively small.

Relative Cost - This technology would involve high capital and O&M costs over a short period, approximately one or two years.

Conclusion - This process option is not retained for either aquifer because of effectiveness and implementability issues.

2.7.7.2 Air Sparging

Air sparging involves the injection of air or oxygen into the contaminated aquifer. Injected air strips VOCs into the unsaturated zone. SVE is usually implemented in conjunction with air sparging to remove the vapor-phase contamination from the vadose zone by vacuum extraction and vapor treatment and to mitigate impacts to surface receptors.

Effectiveness - Air sparging, properly installed and operated, is generally most effective for removal of volatile, relatively insoluble organics from a highly permeable, relatively uniform sandy aquifer (Bass 2000). Oxygen added to the contaminated groundwater can enhance aerobic biodegradation of contaminants below and above the water table. The saprolite is highly permeable but not sandy, and the permeability of the bedrock aquifer is along the bedding planes. Controlling the migration of the sparged vapors in fractured bedrock systems where the pathways may follow the orientation of fractures could be problematic. Since air sparging treats the dissolved phase, back diffusion and desorption from mass stored in the aquifer matrix could make it difficult to achieve RAOs within a reasonable timeframe.

Implementability - Effective vapor capture would be difficult to implement at the site because the saprolite is a confined aquifer. The vadose zone (where the vapor extraction wells would be screened) is a low permeability clay, and therefore the radius of influence of the vapor extraction wells would be prohibitively small

Relative Cost - This technology would involve moderate capital and O&M costs.

Conclusion - This process option is not retained for further evaluation due to lack of effectiveness and implementability.

2.7.7.3 In-Situ Chemical Reduction

The most widely used reductant for reducing chlorinated hydrocarbons is ZVI. ZVI has been applied in several ways to remediate contaminants: in a permeable reactive barrier; in nano scale through injection; in micro-scale through injection or with hydraulic fracturing. Recently, ZVI has also been combined with organic carbon amendments for in-situ remediation, for example, EZVI is a proprietary product developed by National Aeronautics and Space Administration containing emulsified oil coated ZVI; and EHC is a proprietary product developed by Adventus containing ZVI and controlled-release carbon in a solid form.

Effectiveness- ZVI and the associated proprietary products can effectively treat groundwater containing PCE and its degradation byproducts. Achieving uniform delivery of the reductant and adequate contact of reductant with contaminants would be critical for effective treatment. Most of the contaminant destruction would occur in the flow paths. Since ZVI is a particle, limited diffusion into the matrix would occur. However, ZVI is long lasting; concentration gradients would form that would promote back-diffusion of contamination out of the matrix and into the reactive zone.

Implementability - Achieving uniform delivery is the key implementation hurdle for in-situ chemical reduction. Injection is believed to be capable of distributing the reductant uniformly in the relatively porous saprolite. In the bedrock, injection would emplace the ZVI along existing fractures and bedding planes. To expand beyond these existing features would require hydraulic fracturing. However, fracturing could potentially connect previously unconnected bedding planes, leading to further migration of the contamination.

Cost - This technology would involve high capital cost; depending on the delivery technology and the depth required to be achieved, the O&M cost could be minimal, mainly from a monitoring cost standpoint.

Conclusion - This process option using ZVI in combination with an organic substrate is retained for further evaluation for the saprolite and the bedrock. Distribution of the ZVI and organic combined amendment may be challenging.

2.7.7.4 In-Situ Chemical Oxidation

ISCO is an aggressive approach that involves the injection of chemical oxidants into the subsurface that destroy organic contaminants in groundwater. Complete oxidation of contaminants results in their breakdown into less toxic compounds such as carbon dioxide, water, and chloride. The commonly used oxidants include ozone, Fenton's Reagent, permanganate, activated persulfate, catalyzed percarbonate, etc. Permanganate and activated persulfate can oxidize PCE, TCE, and vinyl chloride effectively and are relatively stable in the subsurface.

Factors that must be considered when implementing ISCO include site-specific geology, the ability to distribute the oxidants into the contaminated media, and the soil oxidant demand. The effectiveness of ISCO treatment is dependent on distributing the oxidant to achieve direct contact between the oxidants and the contaminants. This can be very challenging in heterogeneous geology. ISCO is a non-selective oxidation process. The oxidants would react with the contaminants and naturally occurring compounds in soil, including organic compounds and select metals. Thus, an excess amount of oxidants would be required to satisfy the oxidant demand of the native soil. ISCO treatment results in an oxidizing condition within the treatment area, which would hinder the natural reductive dechlorination processes temporarily.

Effectiveness - The effectiveness of ISCO treatment largely would depend on delivery: achieving adequate contact between oxidants (especially the radicals) and contaminants. Subsurface heterogeneities could affect delivery of the oxidant. Poor application could result in large pockets of untreated contaminants and the oxidant could be consumed by soil. ISCO would not be cost effective to treat the contaminant plume at low concentrations because the volumes are very large and most of the oxidants would be consumed to meet soil oxygen demand. Thus ISCO would be most effective in the saprolite where concentrations are above 1ppm total VOCs, and likely less effective in the more dilute concentrations observed in the bedrock.

Implementability - Equipment and vendors would be available for ISCO implementation, but may have to travel from the continental US. Achieving uniform delivery is the key implementation hurdle. Injection is believed to be capable of distributing the oxidant uniformly in the relatively porous saprolite. In bedrock, injection would distribute amendment primarily along existing fractures and bedding planes. To expand beyond these features (into the bedrock matrix) would require hydraulic fracturing. However, fracturing could potentially connect previously unconnected bedding planes, leading to further migration of the contamination.

Relative Cost - ISCO would involve high capital and low O&M costs.

Conclusion - ISCO is retained for further evaluation in the saprolite and the bedrock. It would not be used to treat low level contamination because it would not be cost-effective.

2.7.7.5 In-Situ Bioremediation

In-situ bioremediation technology biologically transforms chlorinated VOCs into non toxic compounds over a wide range of concentrations in groundwater. The degradation mechanisms for site contaminants are discussed in Section 2.6.4. Aerobic cometabolic degradation pathways will not be considered because the major contaminant is PCE, which cannot be degraded through this pathway.

Enhanced anaerobic biodegradation (EAB) involves the injection of an electron donor, nutrients, and/or dechlorinating microorganisms (i.e., bioaugmentation) as necessary into the subsurface. This combined delivery stimulates the natural reactions of microorganisms to degrade chlorinated solvent contamination in an environment otherwise low in organic content. Additionally, the reducing conditions can lead to the formation of reduced iron minerals in the subsurface that create abiotic degradation pathways for VOCs (Adamson et al. 2011)

Common electron donors include lactate, whey, emulsified vegetable oil (EVO), and integrated carbon and ZVI. Lactate and whey generally last three to six months in the subsurface, while EVO and the integrated carbon and ZVI may last for two or three years. Whey potentially could enhance dissolution of DNAPL, if present, to expedite the bioremediation process.

The bioremediation process can generate secondary impacts, especially the solubilization of iron and manganese, and generation of methane and carbon dioxide. These impacts are the result of the enhanced reducing conditions in the groundwater (iron and manganese solubilization) and degradation of the contaminants by microbes (methane and carbon dioxide generation). The iron and manganese precipitate once oxidizing conditions return to the treatment zone, and the methane will dilute and disperse (ITRC 2008). These impacts are transient, but the recovery processes can take years depending upon the rate of reoxygenation of the treatment zone.

Effectiveness - In-situ bioremediation has been successfully applied at many sites. The relatively high groundwater temperature in Puerto Rico (24 °C and above) is conducive to microbial growth. The plume in the saprolite and bedrock are mostly anaerobic (dissolved oxygen less than 1 mg/L), and have low concentrations of competing electron acceptors (nitrate, sulfate). The presence of methane in the groundwater indicates that methanogenic conditions may be present in some parts of the aquifer. As was identified during the analysis of MNA, limited naturally occurring organic carbon may be limiting growth of microbes. Introductions of a carbon source such as EVO would provide the carbon substrate necessary for microbial growth. Given the lack of detected vinyl chloride, the groundwater may need to be augmented with dechlorinating bacteria in addition to carbon substrate. Overall, the existing data indicate that bioremediation would be effective in both the saprolite and the bedrock.

Implementability - Effectively delivering the amendment into the plume would be critical for the success of in-situ treatment. For this site, the large areal extent of contamination and the depth to groundwater would make amendment delivery costly. In addition, repeated injections would likely be necessary for all electron donors. High groundwater flow velocities in the saprolite would mitigate the cost to an extent, since advection could be harnessed in part to distribute amendment. The high flow rates would also likely speed the recovery time from the secondary impacts.

In the bedrock, upgradient injection of amendments and groundwater extraction may be considered to enhance amendment distribution. The implementability of this type of system is unknown at this time. A pump test would likely be necessary to identify the location of injection and extraction points, and potential effectiveness of amendment distribution in the bedrock plume. Due to the depth of the bedrock aquifer and complex flow regime, secondary impacts may persist longer in the bedrock than in the saprolite.

Relative Cost - This technology would involve medium to high capital and low O&M costs.

Conclusion - In-situ bioremediation is retained for further evaluation for both the saprolite and bedrock aquifers.

2.7.8 Discharge

When groundwater extraction and ex-situ treatment are used, the treated water could be discharged on-site or off-site. Potential on-site and off-site discharge options for groundwater are evaluated below.

2.7.8.1 On-Site Injection

The on-site discharge technology involves injecting treated groundwater into the aquifer using a series of wells. The injection can be used as part of a hydraulic control design. The extracted groundwater would need to be treated to applicable groundwater standards prior to disposal to the subsurface. Generally, the on-site injection system would be operated in the same timeframe as the groundwater extraction system, which can run for many years.

Effectiveness - The effectiveness of this option would rely on proper injection well design and construction, including adequate pipe sizing, proper placement of the wells, and reliable construction materials.

Implementability - Discharge of treated effluent to a series of injection wells is easily implementable, using available construction resources and equipment. Some implementability problems could arise during long-term operation of injection wells, such as clogging of screen packs with precipitates or microbial fouling, particularly in high iron conditions. These problems could theoretically be overcome by proper removal of suspended solids and excess iron from the treated water, periodic chlorination of the injected water, and redevelopment and cycling on/off of wells. Discharge of treated effluent may be required to meet substantive requirements of EPA UIC permit and the PRWQS (March 2010).

Relative Cost - This technology would involve medium capital costs due to the depth of drilling required and the extent of the site, and medium to high O&M costs if well rehabilitation would need to be performed periodically.

Conclusion - Injection is retained.

2.7.8.2 On-Site Surface Recharge

Groundwater can be disposed on-site using a surface recharge system such as an excavated recharge basin. Recharge basins are shallow, man-made ponds that allow water to infiltrate gradually into the ground. Depending on the permeability of the soil, recharge basins generally require large surface areas. As with injection wells, on-site recharge requires that the extracted groundwater be treated to meet applicable groundwater standards prior to discharge.

Effectiveness - On-site surface recharge would not be effective for this site because the overburden is clay and silty/clay, and likely has a very slow infiltration rate.

Implementability - Surface recharge disposal would be readily implementable, as standard construction methods and materials would be utilized. However, space is limited at this site to construct a large recharge basin.

Relative Cost - A surface recharge system would involve low capital and O&M costs.

Conclusion - Surface recharge is not retained for further evaluation due to lack of effectiveness and implementability.

2.7.8.3 Surface Water Discharge

Treated groundwater can be discharged to a surface water body, such as the nearby Rio Arroyata. Disposal to an off-site surface water body would require that the extracted groundwater be treated to meet applicable surface water discharge standards.

Effectiveness - Discharge to a surface water body such as the Rio Arroyata would be an effective method for disposal of treated groundwater.

Implementability - Discharge to a surface water body is easily implementable using available construction resources. Implementability would depend in part on the location of the treatment building, and potential to route piping to the Rio Arroyata. This process option would be required to meet substantive requirements of NPDES permits and PRWQS (March 2010) for discharge.

Relative Cost - This technology would involve low capital and O&M costs.

Conclusion - Surface water body discharge is retained for further evaluation.

2.7.8.4 Discharge to Publicly Owned Treatment Works

This process option would involve off-site discharge of treated groundwater or treatment waste residuals to a publicly owned treatment works (POTW) facility via a sanitary sewer. Cidra is served by a POTW approximately two miles from the site.

Effectiveness - This would be an effective option since there are sanitary sewers in the vicinity of the site and the treated water meets the wastewater treatment facility requirements and intake capacity.

Implementability - Discharge to sanitary sewers would be implementable using available construction resources if sanitary sewer system is present near the site. Discharged water may require pre-treatment to meet the facility acceptance requirements. The discharge technology must be combined with extraction and ex-situ treatment.

Relative Cost - Discharge to POTW would involve low capital and medium O&M costs.

Conclusion - Sanitary sewer discharge is retained.

2.8 Identification and Screening of Remedial Technologies and Process Options for Soil Vapors

2.8.1 Engineering Controls

Engineering controls consist of installation of vapor mitigation systems to prevent or reduce toxic vapors emitted by contaminated soil and groundwater from entering into buildings, thus reducing the human health risk. Several vapor mitigation technologies are available for new and existing buildings including passive venting, sub-slab depressurization (SSD), sub-membrane depressurization, sub-slab pressurization, building pressurization, and sealing building cracks and holes. The most commonly used vapor mitigation system is an SSD system. This system withdraws the contaminant vapor from underneath the building foundation based on natural or engineering-created pressure differences and discharges the vapor into the air above the roofline. A membrane can be installed on top of the foundation slab to reduce the migration of toxic vapors into the building and enhance the efficiency of an SSD system. In existing buildings this would involve the demolition of the floor slab prior to the membrane installation.

Engineering controls do not reduce the toxicity, mobility, or volume of contamination, and generally require long-term monitoring of contaminant concentrations and migrations.

Effectiveness – Vapor mitigation systems can effectively reduce toxic vapor concentrations inside buildings. It is a proven technology that has been widely used. Sub-slab sampling would be required to determine the necessity of installation of such a system and the duration of operation.

Implementation – This technology can be easily implemented.

Relative cost – The cost for this technology is low.

Conclusion – Engineering controls are retained for further consideration.

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Section 3

Development and Screening of Remedial Action Alternatives

3.1 Overview

In this section, remedial action alternatives (herein referred to as remedial alternatives) are assembled by combining the retained remedial technologies and process options presented in Section 2 for each contaminated media. Remedial alternatives are developed from either stand-alone process options or combinations of the retained process options.

The remedial alternatives for the site span a range of categories defined by the NCP as follows:

- No action alternative
- Alternatives that address the principal threats but involve little or no treatment include those where protection would be by prevention or control of exposure through actions such as containment, engineered controls, and/or institutional controls
- Alternatives that, as their principal element, employ treatment that reduces the toxicity, mobility, or volume of the contaminants, that may be innovative
- Alternatives that remove or destroy contaminants to the maximum extent, eliminating or minimizing long-term management

The technologies and process options retained for soil as either primary, secondary, or contingency components include the following:

- No Action
- Institutional/engineering controls including land use controls, fencing and signage, and monitoring
- Containment (capping)
- Removal (excavation)
- In situ thermal remediation
- In situ bioremediation
- Soil vapor extraction
- Environmental fracturing
- Electrokinetics

- In situ chemical reduction
- In situ chemical oxidation
- Low temperature thermal desorption
- Off-site disposal

The technologies and process options retained for vapor as either primary, secondary or contingency components include the following:

- Engineering Controls

The technologies and process options retained for groundwater as either primary, secondary or contingency components include the following:

- No Action
- Institutional/engineering controls including land use controls, community awareness, and monitoring
- Groundwater extraction wells
- Ex-situ Treatment
  - Air Stripping
  - GAC
  - Ultraviolet/Oxidation
  - Potassium permanganate oxidation
- In situ treatment
  - Chemical Reduction
  - Chemical Oxidation
  - Bioremediation
- On site injection
- Surface water discharge
- Discharge to POTW

In some cases, an alternative description may include a general technology for a portion of the remedy (e.g., in-situ treatment for contaminated source zone areas). This generalized description is necessary so that the Record of Decision (ROD) may allow site-specific bench-scale or pilot testing of several technology process options (e.g., in-situ treatment). This flexibility will allow the most successful technology to be selected and designed for full-scale implementation. In these cases, a representative remedial technology process option is selected during the FS to simplify the analysis and comparison of alternatives, while it is understood that the alternative will allow flexibility in the final design.

3.2 Assumptions Affecting Development of Remedial Alternatives

Two fundamental assumptions affect the development of remedial alternatives evaluated in this FS (other than the "no action alternative").

- Remedial alternatives that require an indefinite duration of O&M will be evaluated for a default 30-year period.
- The on-site buildings will not be fully demolished because they are structurally sound and could be reused for other purposes in the future. However, due to limited space at the IDC facility, implementation of some treatment remedies would call for the building to be slightly modified.

Note that changes to site conditions or the current understanding of site conditions may expand the list of assumptions, which in turn, may impact the remedial alternatives developed for the site.

3.3 Description of Soil Remedial Action Alternatives

Remedial alternatives were assembled by combining the retained remedial technologies and process options for each contaminated media. Because there is a lack of groundwater contamination at IDC, less aggressive treatment technologies are proposed for that property, as opposed to Ramallo where more aggressive treatment technologies are proposed in order to reduce the impact to groundwater. Table 2-5 provides a comprehensive list of the remedial technologies/process options that are used for each remedial alternative. The fundamental site assumptions and factors described in Section 3.2 were also considered during development of the remedial alternatives.

The remedial alternatives to address soil contamination at the site are presented below.

Soil Alternatives for IDC

- Alternative IDC-S1: No Action
- Alternative IDC-S2: Containment
- Alternative IDC-S3: Soil Vapor Extraction and Containment

Soil Alternatives for Ramallo

- Alternative R-S1: No Action
- Alternative R-S2: Containment
- Alternative R-S3: Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment

- Alternative R-S4: In Situ Chemical Treatment and Containment

3.3.1 Common Elements

There are several common elements which are assumed to be included as part of each remedial alternative. With the exception of Five-Year site reviews, the common elements listed below do not apply to the No Action alternatives. The common elements include the items below.

Pre-Design Investigation – A structural survey of buildings bordering the remediation target zone would be conducted to evaluate structural stability during and after remediation. The extent of contamination would be fully delineated.

Vapor Mitigation Systems - An additional component included in all soil alternatives (except the no action alternative) is the possibility of the installation of vapor mitigation systems dependent upon sampling results conducted during the RI and the one-time inspection of the vapor mitigation systems that may be installed. Vapor sampling would include collection of two samples at each building including sub-slab and indoor air samples. If vapor sampling indicates the presence of vapors exceeding the air criteria, a vapor mitigation system would be installed. A one-time inspection of the vapor mitigation systems would be conducted to ensure that the systems are working properly. For cost estimating purposes, it is assumed that 2 buildings would require installation of a vapor mitigation system. Following installation, these buildings would need to be sampled to ensure mitigation system performance.

Institutional controls – Institutional controls should restrict the future use of the site until cleanup is complete.

Five-Year Site reviews – Per CERCLA, alternatives resulting in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, require that the site be reviewed at least once every five years. If justified by the review, additional remedial actions may be implemented to remove, treat, or contain the contamination. The site review would include a site-wide visual inspection and a report prepared by EPA.

3.3.2 Detailed Description of Soil Remedial Alternatives

3.3.2.1 IDC Soil Alternatives

3.3.2.1.1 Alternative IDC-S1: No Action

The No action alternative was retained in accordance with the NCP requirement to serve as a baseline for comparison with the other alternatives. Under this alternative, no action would be taken to remedy the contaminated soil to address the associated risks to the environment. Because this alternative would result in contaminants remaining on site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years. If justified by the review, remedial actions may be implemented to remove or treat the wastes.

3.3.2.1.2 Alternative IDC-S2: Containment

A cap would be installed at the site on the unpaved areas where rainwater may infiltrate into the contaminated soils. The existing building would also serve to cap underlying contaminated soils. The purpose of a cap would be to reduce rainwater infiltration as much as possible and thus slow any further infiltration-induced migration of contaminants in the vadose zone. Capping would not meet soil PRGs across the majority of the site because soil contamination would be left in place. However, contaminant concentrations may slowly reduce over time (decades to centuries) due to biodegradation and volatilization. Since there is little groundwater contamination at IDC, this less aggressive remedial alternative would be sufficient to meet the RAOs. For cost-estimating purposes, it is assumed that the cap will consist of concrete overlaying the existing clay soils. Regular monitoring and maintenance of the cap would be required in perpetuity, as well as institutional controls to restrict incompatible use of the property in the future.

3.3.2.1.3 Alternative IDC-S3: Soil Vapor Extraction and Containment

Under this alternative, the hot spot would be targeted with soil vapor extraction, and capping would be implemented as described above for Alternative IDC-S2. For cost estimating purposes, it is assumed that the hotspot in the alleyway would be treated with SVE, approximately 100 square feet and 20 feet deep. The actual extent of the principal threat wastes to be targeted with SVE would be determined during a pre-design investigation.

Since the site soils are low-permeability clay, air flow through the soil is expected to be low and treatment with SVE is likely to require closely spaced wells. The compressor for the system and a vapor treatment system would be installed in the IDC building. It is anticipated that the system would run for up to ten years. Capping would still need to be relied upon to meet RAOs over the long-term.

3.3.2.2 Ramallo Soil Alternatives

3.3.2.2.1 Alternative R-S1: No Action

The No action alternative was retained in accordance with the NCP requirement to serve as a baseline for comparison with the other alternatives. Under this alternative, no action would be taken to remedy the contamination soil to address the associated risks to the environment. Because this alternative would result in contaminants remaining on site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years. If justified by the review, remedial actions may be implemented to remove or treat the wastes.

3.3.2.2.2 Alternative R-S2: Containment

In the same manner as described for the IDC capping alternative above, a cap would be installed at Ramallo on the unpaved areas where rainwater may infiltrate into contaminated soils, and the existing building would function as a cap of underlying contaminated soils. Repair would be made to existing concrete cover as necessary.

3.3.2.2.3 Alternative R-S3: Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment

For this alternative, soil vapor extraction would be enhanced by thermal heating of the treatment zone. A hollow stem auger would be used inside and outside the building to advance combined SVE wells and heating electrodes to the bottom of the treatment zone on approximately 20-foot centers. The electrical equipment, compressor for the system and the vapor and condensate treatment system would be located on the Ramallo property. Elevated PCE concentrations that exceed the principal threat waste criterion were detected at the surface. Surface soil contamination would be excavated and disposed off-site in a RCRA Subtitle C landfill. A cap would then be installed across the extent of the remediation target zone to minimize infiltration of rainwater into the contaminated soil. The cap would need to be inspected and maintained indefinitely.

3.3.2.2.4 Alternative R-S4: In Situ Treatment and Containment

Under this alternative, in situ chemical treatment would be used to remediate the high-concentration soils, and the remainder of the remediation target zone would be capped.

As discussed in Section 2, the presence of degradation byproducts of PCE—including vinyl chloride—indicate that the clay is moist enough to sustain biological growth, the redox conditions are amenable to reductive dechlorination, and the existing microbes are capable of destroying the contaminants at the site. Under this alternative, amendments would be introduced to provide a carbon source for further growth of the dehalogenating microbes. Several types of amendments and amendment delivery processes have been identified, evaluated, and retained. The most cost effective amendment and delivery process would be determined during the design phase. For alternative development and cost-estimating purposes, a combined ISCR/bioremediation amendment is chosen because it is long-lasting and would also promote abiotic degradation; amendment would be introduced with mechanical mixing in the surface soils, and the amendment would be distributed with hydraulic fracturing in the deeper intervals since injection alone in the low permeability clay would be ineffective. Hydraulic fracturing would not be performed in the first ten feet to avoid damaging nearby building foundations. Hydraulic fracturing will have the added benefit of introducing more of the moisture necessary for biological growth. To minimize the possibility of the injected liquids mobilizing contaminant mass into the underlying saprolite aquifer, the deepest part of the target zone will be treated first to provide a reactive barrier to any induced contaminant migration from fracturing occurring above. Since the injected amendment will induce bioremediation in saturated aquifer conditions as well as in the vadose zone, the inadvertent emplacement of amendment in the saprolite aquifer would not be of consequence.

3.4 Description of Groundwater Remedial Action Alternatives

The remedial alternatives to address groundwater contamination at the site are summarized below.

- Alternative GW1: No Action
- Alternative GW2: Groundwater Extraction, Treatment, and Long-term Monitoring
- Alternative GW3: Focused Groundwater Extraction, Treatment, and Long-term Monitoring
- Alternative GW4: In situ Treatment and Long-term Monitoring

3.4.1 Common Elements

Several common elements are assumed to be included as part of each remedial alternative. With the exception of five year site reviews, the common elements listed below do not apply to the No Action alternative. The common elements include the items below.

<u>Pre-Design Investigation</u> – The nature and extent of groundwater contamination would be fully delineated. Design parameters would also be obtained during the pre-design investigation.

Long-term Monitoring – Periodic monitoring of site groundwater would be implemented when contaminants remain above levels that allow for unrestricted use and unlimited exposure. The monitoring program should continue until concentrations have met remedial goals. Long-term monitoring is the only remedial action suggested for groundwater contamination at the IVAX facility. Since the observed 1,1-DCE concentrations are only slightly above PRGs, it would not be cost effective to treat this contamination. In addition, it would be prudent to monitor Rio Arroyata surface water for impacts to water quality from remediated groundwater discharging to the Rio if an extraction, treatment, and disposal alternative for groundwater is selected.

Institutional controls –Institutional controls should restrict the future use of the site and groundwater until cleanup is complete.

Five-Year Site reviews – Per CERCLA, alternatives resulting in contaminants remaining above levels that allow for unrestricted use and unlimited exposure, require that the site be reviewed at least once every five years. If justified by the review, additional remedial actions may be implemented to remove, treat, or contain the contamination. The site review would include evaluation of data collected from the long-term monitoring, a site-wide visual inspection and a report prepared by EPA.

3.4.2 Detailed Description of Groundwater Remedial Alternatives

3.4.2.1 Alternative GW1: No Action

A "no action" alternative is required by the NCP to provide an environmental baseline against which impacts of the various remedial alternatives can be compared. Under this alternative, no action would be taken to remediate the contaminated groundwater or to monitor contaminant concentrations to address the associated risks to human health or the environment. Because this alternative would result in contaminants remaining on-site above levels that allow for unrestricted use and unlimited exposure, CERCLA requires that the site be reviewed at least once every five years. If justified by the review, remedial actions may be implemented to remove or treat the wastes.

3.4.2.2 Alternative GW2: Groundwater Extraction, Treatment, and Long-Term Monitoring

Under this alternative, the full extent of the groundwater plume contaminated above PRGs would be targeted for remediation. Groundwater extraction, treatment, and disposal would be implemented in both the saprolite and the bedrock inside the MCL (5 µg/L PCE) plume isocontour. Groundwater extraction would serve to extract contamination from the aquifer, and also create a hydraulic barrier to further contaminant migration into the bedrock and downgradient. Extraction and treatment would continue until the aquifer has been restored to the extent practicable. Long-term groundwater monitoring of contaminants in the saprolite and bedrock aquifers would be performed to assess remedial action performance.

Matrix diffusion—the retention of contaminants in low-permeability layers—has caused the extension of times for cleanup at many groundwater extraction systems in the past. The extent of matrix diffusion has not been measured or modeled at the site.

For the aboveground treatment train, influent flow equalization, bag filtration, air stripping, and treatment with activated carbon and potassium permanganate oxidation is proposed for costing purposes. Air stripping involves the mass transfer of volatile contaminants from water to air by increasing the surface area of the groundwater exposed to air. Given the presence of low levels of vinyl chloride, the most cost-effective vapor phase treatment train for the air stripper off-gas will be to remove PCE and TCE with granular activated carbon, followed by treatment with potassium permanganate oxidation to remove cis-1,2-DCE and vinyl chloride. It is assumed that the water effluent from the air stripper will be polished with activated carbon to meet Puerto Rico standards and then discharged to surface water.

The presence of soluble iron in the groundwater can lead to iron fouling. In 14 samples for iron in the saprolite, the mean concentration was 2.5 mg/L with a standard deviation of 4.7 mg/L. Assuming that these are measurements of soluble iron, these concentrations indicate that iron fouling is possible. It is assumed that a metals sequesterant will be added as a chemical feed to the influent flow equalization tank.

This alternative would require additional wells, pump tests, hydraulic conductivity measurements, and modeling. A long term monitoring program would be instituted in distal parts of the plume.

3.4.2.3 Alternative GW3: Focused Groundwater Extraction, Treatment, and Long-Term Monitoring

Under this alternative, groundwater extraction, treatment, and disposal would be implemented in the saprolite aquifer inside a focused area which would be determined during the remedial design phase based upon modeling to optimize extraction well locations to prevent extraction of clean water. Groundwater extraction would serve to extract contamination from the aquifer, and also create a hydraulic barrier to limit further contaminant migration into the bedrock and downgradient. Extraction and treatment would continue until the aquifer has been restored to the extent practicable. For areas outside of the extraction and treatment zone, long-term monitoring of the saprolite and bedrock aquifers would be performed to assess degradation of contaminants.

Matrix diffusion—the retention of contaminants in low-permeability layers—has caused the extension of times for cleanup at many groundwater extraction systems in the past. The extent of matrix diffusion has not been measured or modeled at the site.

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This alternative would require additional wells, pump tests, hydraulic conductivity measurements, and modeling. A long term monitoring program would be instituted in distal parts of the plume.

3.4.2.4 Alternative GW4: In Situ Treatment and Long-Term Monitoring

In the saprolite, in situ treatment would be implemented under this alternative within a focused isocontour that would be determined after the pre-design investigation. This is anticipated to be a chemical or biological treatment process that would target the most contaminated areas of the saprolite in a cost-effective way.

During the remedial design phase, numerical groundwater modeling would be performed to determine if a permeable reactive barrier would need to be installed across the thickness and width of the saprolite target zone at a location downgradient in order to treat the downgradient PCE plume. The exact location would be determined after a treatability and/or pilot study to determine the technical limitations (in terms of concentrations of VOCs that could be degraded) of the PRB. Over time, advection would move the contamination in the plume through the permeable reactive barrier. In this way, RAOs would eventually be met inside the saprolite plume. It is assumed that the PRB would need to be periodically refreshed or reinstalled when reactivity fades.

This alternative would require treatability studies to identify the most cost-effective treatment amendment, additional wells, pump tests, hydraulic conductivity measurements, and modeling. A long term monitoring program would be instituted in distal parts of the plume. In situ treatment would continue until the aquifer has been restored to the extent practicable. For areas outside of the in situ treatment zone, long-term monitoring of the saprolite and bedrock aquifers would be performed to assess degradation of contaminants.

3.5 Selection of Alternatives for Further Evaluation

Since only a limited number of remedial alternatives were developed, all alternatives will be carried forward for detailed analysis. Screening of remedial alternatives will not be performed.

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Section 4

Detailed Analysis of Remedial Action Alternatives

The soil and groundwater alternatives carried forward are evaluated in this section against the criteria described below.

4.1 Evaluation Criteria

EPA's nine evaluation criteria address statutory requirements and considerations for remedial actions in accordance with the NCP and additional technical and policy considerations that have proven to be important for selecting among remedial alternatives (EPA 1988). The following subsections describe the eight evaluation criteria used in the detailed analysis of remedial alternatives.

4.1.1 Overall Protection of Human Health and the Environment

Each alternative is assessed to determine whether it can provide adequate protection of human health and the environment (short- and long-term) from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site. Evaluation of this criterion focuses on how site risks are eliminated, reduced, or controlled through treatment, engineered controls, or institutional controls and whether an alternative poses any unacceptable cross-media impacts.

4.1.2 Compliance with ARARs

Section 121(d) of CERCLA, 42 USC § 9621(d), the NCP, 40 CFR Part 300 (1990), and guidance and policy issued by EPA require that remedial actions under CERCLA comply with substantive provisions of ARARs from the State (herein, the Commonwealth) and Federal environmental laws and Commonwealth facility siting laws during and at the completion of the remedial action.

4.1.2.1 Identification of ARARs

The definition and identification of ARARs have been described and discussed in detail in Section 2.3. Three classifications of requirements are defined by EPA in the ARAR determination process. ARARs are defined as chemical-, location-, or action-specific. An ARAR can be one or a combination of all three types of ARARs. The Federal and Commonwealth of Puerto Rico ARARs for the site are listed in Tables 2-1 through 2-3. Each alternative is evaluated to determine how chemical-, location-, and action-specific ARARs identified in the ROD would be met.

4.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness evaluates the likelihood that the remedy would be successful and the permanence that it affords. Factors to be considered, as appropriate, are discussed below.

- Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals are considered to the degree that they remain hazardous, taking into account their T/M/V and propensity to bioaccumulate.

- Adequacy and reliability of controls that are used to manage treatment residuals and untreated waste remaining at the site. This factor includes an assessment of containment systems and institutional controls to determine if they are sufficient to ensure that any exposure to human and ecological receptors is within protective levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals, the assessment of the potential need to replace technical components of the alternative, and the potential exposure pathways and risks posed should the remedial action need replacement.

4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Each alternative is assessed for the degree to which it employs a technology to permanently and significantly reduce T/M/V including how treatment is used to address the principal threats posed by the site. Factors to be considered, as appropriate, include the items below.

- The treatment processes the alternatives employ, and materials they would treat
- The amount of hazardous substances, pollutants, or contaminants that would be destroyed or treated, including how the principal threat(s) would be addressed
- The degree of expected reduction in T/M/V of the waste due to treatment
- The degree to which the treatment is irreversible
- The type and quantity of residuals that would remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous substances and their constituents
- Whether the alternative would satisfy the statutory preference for treatment as a principal element of the remedial action

4.1.5 Short-term Effectiveness

This criterion reviews the effects of each alternative during the construction and implementation phase of the remedial action until remedial response objectives are met. The short-term impacts of each alternative are assessed, considering the following factors, as appropriate.

- Short-term risks that might be posed to the community during implementation of an alternative
- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures
- Potential adverse environmental impacts resulting from construction and implementation of an alternative and the reliability of the available mitigation measures during implementation in preventing or reducing the potential impacts
- Time until protection is achieved for either the entire site or individual elements associated with specific site areas or threats.

4.1.6 Implementability

The technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation is evaluated under this criterion. The ease or difficulty of implementing each alternative is assessed by considering the following factors detailed in Exhibit 4-2.

Exhibit 4-2 Implementability Factors to be Considered during Alternative Evaluation

Criterion	Factors to be Considered
Technical Feasibility	Technical difficulties and unknowns associated with the construction and operation of a technology Reliability of the technology, focusing on technical problems that will lead to schedule delays Ease of undertaking additional remedial actions, including what, if any, future remedial actions would be needed and the difficulty to implement additional remedial actions Ability to monitor the effectiveness of the remedy, including an evaluation of risks of exposure should monitoring be insufficient to detect a system failure
Administrative Feasibility	Activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions)
Availability of Services and Materials	Availability of adequate off-site treatment, storage capacity, and disposal capacity and services Availability of necessary equipment and specialists and provisions to ensure any necessary additional resources Availability of services and materials plus the potential for obtaining competitive bids, which is particularly important for innovative technologies Availability of prospective technologies

4.1.7 Cost

Detailed cost estimates for each alternative were developed for the Final FS according to *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000a). Detailed cost estimates for this alternative are included in Appendix A and include the following:

- Capital costs
- Annual O&M costs
- Periodic costs

- Present value of capital and annual O&M costs

4.1.8 Commonwealth (Support Agency) Acceptance

Commonwealth (support agency) acceptance is a modifying criterion under the NCP. Assessment of commonwealth acceptance will not be completed until comments on the Final FS Report are submitted to EPA. Thus, Commonwealth acceptance is not considered in the detailed analysis of alternatives presented in the FS.

4.1.9 Community Acceptance

Community acceptance is also a modifying criterion under the NCP. Assessment of community acceptance will include responses to questions that any interested person in the community may have regarding any component of the remedial alternatives presented in the Final FS Report. This assessment will be completed after EPA receives public comments on the Proposed Plan during the public commenting period. Thus, community acceptance is not considered in the detailed analysis of alternatives presented in the FS.

4.3 Detailed Analysis of Remedial Alternatives

This section provides detailed descriptions and analysis of the remedial alternatives developed in Section 3 for the site. The remedial alternatives retained for detailed analysis are summarized below.

Soil Alternatives for IDC

- Alternative IDC-S1: No Action
- Alternative IDC-S2: Containment
- Alternative IDC-S3: Soil Vapor Extraction and Containment

Soil Alternatives for Ramallo

- Alternative R-S1: No Action
- Alternative R-S2: Containment
- Alternative R-S3: Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment
- Alternative R-S4: In situ Treatment and Containment

Groundwater Alternatives

- Alternative GW1: No Action
- Alternative GW2: Groundwater Extraction, Treatment, and Long-term Monitoring
- Alternative GW3: Focused Groundwater Extraction, Treatment, and Long-term Monitoring
- Alternative GW4: In situ Treatment and Long-term Monitoring

4.3.1 Common Elements

4.3.1.1 Common Elements for Soil Alternatives

A pre-design investigation is a common element of the soil alternatives (not including the No Action alternative). The intent of the investigation would be to fully delineate the contamination at the site and gather necessary inputs for the design.

An additional component included in all soil alternatives (except the no action alternative) is the possibility of the installation of vapor mitigation systems dependent upon sampling results (covered under the RI/FS budget) and the one-time inspection of the vapor mitigation systems installed. Vapor sampling would include collection of two samples at each building including sub-slab and indoor air samples. If vapor sampling indicates the presence of vapors exceeding the air criteria, a vapor mitigation system would be installed. A one-time inspection of the vapor mitigation systems would be conducted to ensure that the systems are working properly. For cost estimating purposes, it is assumed that 2 buildings would require installation of a vapor mitigation system. Following installation, these buildings would need to be sampled to ensure mitigation system performance.

4.3.1.2 Common Elements for Groundwater Alternatives

4.3.1.2.1 Pre-Design Investigation

The intent of a pre-design investigation would be to fully delineate the contamination at the site and gather necessary inputs for the design. Pre-design investigation elements and costs are presented in the cost estimates for each alternative.

4.3.1.2.2 Institutional Controls

The objectives of institutional controls are to prevent exposure to contaminant concentrations above the PRGs, control future development that could result in increased risk of exposure, and prevent the installation of new drinking water wells within contaminated areas. The types of institutional controls employed at the source area would include activity and use restrictions enacted through proprietary (e.g., easements, covenants) and /or governmental (e.g., zoning requirements) controls to prevent use of site areas that would pose an unacceptable risk to receptors. Other controls could include restrictions on installation of drinking water wells and restrictions on groundwater use at locations within the contaminated areas. Information device controls (e.g., warning signs, advisories, additional public education, Notices of Environmental Contamination) would also be employed to limit exposures to contamination. The effectiveness of selected institutional controls would depend on their continued implementation, and their reliability depends on future compliance with the restrictions and inspections that are enforced.

4.3.1.2.3 Long-term Monitoring

The objectives of the long-term monitoring program are outlined below.

- Identify any potentially toxic and/or mobile transformation products
- Assess the effectiveness of remedial action implemented
- Verify that the extent of contamination is not expanding downgradient, laterally or vertically

- Verify no unacceptable impact to potential receptors
- Detect new releases of contaminants to the environment or migration of existing contamination that could impact potential receptors
- Demonstrate the efficacy of institutional controls that were put into place to protect potential receptors
- Verify attainment of RAOs

Monitoring data would be evaluated and used to make decisions regarding the adequacy and continuation of the monitoring program. Decisions resulting from the evaluation of the data may include the topics listed below.

- Continue the monitoring program without change
- Modify the monitoring program
- Modify institutional controls
- Implement a contingency or alternative remedy
- Verify remedial goals have been met and terminate performance monitoring

The primary parameters to be monitored would be the site-related contaminants, geochemical indicators (e.g., oxidation-reduction potential, dissolved oxygen, pH), and hydrogeologic parameters (e.g., elevation of ground water in monitoring wells). Increases and decreases in monitoring frequency may occur over the life of the remedy in response to changes in site conditions and monitoring needs. Long-term monitoring elements and costs are presented in the cost estimates for each alternative.

4.3.2 IDC Soil Alternatives

4.3.2.1 Alternative IDC-S1 – No Action

4.3.2.1.1 Detailed Description of Alternative IDC-S1

The No Action alternative is retained for comparison purposes as required by the NCP. No remedial action would be implemented as part of this alternative. It does not include any institutional controls or monitoring program. Five-year reviews would be conducted by EPA to assess site conditions. No cost is included in the FS for five year reviews since it would be performed by EPA.

4.3.2.1.2 Individual Evaluation of Alternative IDC-S1

Overall Protection of Human Health and the Environment

Alternative IDC-S1, No Action, would not meet the RAOs and would not be protective of the environment since no action would be taken. The site-specific HHRA indicates that the direct contact risks are within EPA's acceptable risk range for soils at IDC. Contamination would remain in the soil, while no mechanisms would be implemented to prevent exposure to contaminated soil, migration to the underlying groundwater, or to reduce the T/M/V of contamination except through natural attenuation processes, which would not be monitored to assess the effectiveness or predict the duration of this alternative.

Compliance with ARARs

This alternative would not achieve chemical-specific ARARs or PRGs. Location- and action-specific ARARs do not apply to this alternative since no remedial action would be conducted.

Long-Term Effectiveness and Permanence

This alternative would not be considered a permanent remedy since no action would be implemented to reduce the level of contamination or verify any naturally occurring reduction. It would not have long-term effectiveness. The potential for migration of contaminants to the saprolite aquifer would not be eliminated. The level and migration of contaminants would not be monitored. Even though natural attenuation processes are occurring, the effectiveness of these natural attenuation processes in reducing the migration of contaminants would remain uncertain.

Reduction of T/M/V through Treatment

No reduction of contaminant T/M/V through treatment would be achieved under this alternative. The total volume of contaminated soil might increase if natural attenuation processes are unable to contain the existing mass. The extent and effectiveness of the toxicity reduction pathway, biodegradation of chlorinated contaminants, would be unknown.

Short-term Effectiveness

Since no remedial action would be implemented at the site, this alternative would not pose short-term risks to on-site workers or the community. It would not have adverse environmental impacts to habitat or vegetation at the site.

Implementability

This alternative could be implemented immediately since no services or permit equivalency would be required.

Cost

There are no capital or O&M costs associated with this alternative.

4.3.2.2 Alternative IDC-S2 – Containment

4.3.2.2.1 Detailed Description of Alternative IDC-S2

A cap would be installed in the alleyway around the IDC building on the unpaved areas where rainwater may infiltrate into the contaminated soils. The purpose of the cap would be to reduce rainwater infiltration as much as possible. The existing building on site would also need to be retained to serve as an effective cap because it diverts rainwater from contaminated soil underlying the building. For cost estimating purposes, it is assumed that the cap would consist of concrete overlying the native clay soils. Figure 4-1 shows the areas to be capped. The components of this alternative are:

- Remedial design
- Cap Installation
- Cap monitoring and maintenance

- Institutional controls
- Five-year reviews

Remedial Design

Data obtained during the RI and pre-design investigation would be used to develop the design. Specifically, concentrations need to be evaluated in existing areas of unpaved areas at IDC in the alleyway in order to ensure that soils requiring containment are identified.

Cap Installation

Cap installation would be completed with widely available construction equipment and techniques. Since the alleyway is narrow, it is anticipated that the cap will be installed using small machinery and by manual labor. The cap would cover the outdoor alleyways in and around the remediation target zone. Approximately 6 inches of concrete would be laid over the unpaved areas on the site. The cap would cover a surface area of approximately 500 square feet, which is anticipated to be larger than the remediation target zone in order to limit any horizontal infiltration of water. The cap would be engineered to limit any infiltration of rainwater into the contaminated soils, meaning that durable, low-permeability material would be used, and rainwater would be directed away from the remediation zone. It is assumed that installation would take place over approximately one week.

Cap Monitoring and Maintenance

The cap would require yearly inspection to look for cracks or other areas where water could seep through and into the soils. For costing purposes, it is assumed that maintenance would be needed every five years to seal cracks or replace deteriorated concrete.

Institutional Controls

Institutional controls (i.e., deed restriction) would be placed on the IDC facility such that any future activities would not damage the cap and allow infiltration of rainwater into the remediation target zone.

Five-Year Review

A five-year review would be conducted every five years using data obtained from the monitoring program. For this alternative, it is assumed that the review would be conducted for 30 years since residual contamination would remain.

4.3.2.2.2 Individual Evaluation of Alternative IDC-S2

Overall Protection of Human Health and the Environment

This alternative would provide conditional protection of the environment. Direct contact risks with the contaminants at IDC are within EPA's acceptable risk range. The cap would be a barrier to direct exposure of contaminated soil to humans and biota and would minimize infiltration of rainwater into the ground. Although data from the RI do not indicate that vadose zone contamination at IDC has impacted groundwater, this could occur in the future if the cap is disturbed and precipitation is allowed to infiltrate into the contaminated soils. Installation of the vapor mitigation system would mitigate risks from vapor intrusion. This alternative would meet the RAOs.

Compliance with ARARs

There are no Federal or Commonwealth chemical-specific ARARs for soil. This alternative would comply with EPA's vapor intrusion screen levels and location-specific and action-specific ARARs. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-Term Effectiveness and Permanence

Magnitude of Residual Risk - This alternative could be effective in the long-term but may not provide a permanent remedy. The contamination would be left in place and potentially could continue to migrate to the underlying groundwater, even though at a slower rate because of the cap. Due to the elevated concentrations of contaminants left in place, the land use would be limited. Any redevelopment would require additional remediation to be performed.

Adequacy of Controls - Capping and deed notices would provide adequate control of the contaminants left in place if the cap is well-maintained and monitored, and the deed notices are heeded. However, routine cap inspection and groundwater monitoring could be difficult to enforce over the long-term, which might result in inadequate control of site contamination.

Reliability of Controls - In order for it to be effective over the long term, the cap would need to be regularly maintained. Over decades, concentrations under the cap may decrease slightly due to volatilization and biodegradation, but not enough to meet PRGs.

Reduction of T/M/V through Treatment

Capping should reduce the mobility of the contamination by limiting migration of contamination via rainwater percolation through the soil. Capping would not reduce toxicity or volume.

Short-term Effectiveness

This alternative would include limited site work and would cause impacts to the workers and surrounding buildings. Use of personal protective equipment (PPE) by workers during remedial operations and sampling would minimize contaminant exposure. The occupants in the IDC building may need to be temporarily relocated during the construction period.

Implementability

This alternative is technically implementable with available equipment, contractors, and materials in Puerto Rico.

Cost

The estimated capital cost for Alternative IDC-S2 is $159,000. The estimated present worth of O&M and monitoring is $46,000. The total present worth is estimated to be $205,000.

4.3.2.3 Alternative IDC-S3 – Soil Vapor Extraction and Containment

4.3.2.3.1 Detailed Description of Alternative IDC-S3

For this alternative, active treatment (soil vapor extraction) would be limited to soils in the alleyway that are determined during the pre-design investigation to be the hot spot (i.e., principal threat waste area). Principal threat waste is estimated to be present across a surface area of 100 square feet to a depth of 20 feet. (Note that highly contaminated soils were found during the RI to a depth of 12 feet in the alleyway. Deeper samples could not be collected because the sampling was done using hand augers and it was not possible to access this area with a rig. The actual depth of contamination would be determined during the remedial design.) The remainder of the remediation target zone would be capped. Figure 4-2 shows areas with SVE treatment as well as capping. This remedial alternative consists of the following major components:

- Building modification
- Pilot study and remedial design
- Cap Installation
- Soil vapor extraction system installation
- Operations and maintenance
- Treatment performance evaluation
- Site restoration
- Institutional controls
- Five-year review

Building Modification

The current configuration of the IDC building is too low and narrow for a drill rig to enter into the remediation target zone. During the remedial action, the building would be modified to provide access to the alleyway. Access doorways would be created on the building front and side to provide access.

Pilot Study and Remedial Design

After the pre-design investigation, a pilot scale field air permeability test would be conducted to determine the achievable air flow rate, the required vacuum to induce the flow, the radius of influence from the applied vacuum, and the initial contaminant removal rates. The air permeability test would be conducted in two phases. Phase I would be a step test to understand the relationship between applied vacuum (or pressure) and the resulting flow. Phase II would involve a constant vacuum (or pressure) and flow rate test. The pilot test might be performed in a clean area as access to the alleyway is difficult without building modifications. The pilot test might take a few weeks to collect all the design parameters. Information gathered would be use to design the system, including the radius of influence of an SVE well, and the size of blowers and carbon vessels.

Cap Installation

Cap installation, inspection, and maintenance would be implemented as described in Alternative IDC-S2.

Soil Vapor Extraction System Installation and Operation

Vertical soil vapor extraction wells would be installed based on the conclusions of the pilot test and pre-design investigation. Nested vapor monitoring wells would also be installed to monitor the progress of contaminant removal and the changes in soil vapor pressure. For cost estimating purposes, three vapor extraction wells would be installed in the hotspot. Two air injection wells would also be installed.

An above ground treatment system would be installed in the IDC building to treat the extracted soil vapor prior to discharge to the atmosphere. This system is anticipated to consist of compressors, piping, and vapor stream treatment. Treated vapor would be discharged through piping to the atmosphere with concentrations that meet Puerto Rico discharge permit requirements.

The operation of the SVE system would likely be continuous at the beginning, then as the contaminant mass removal rate decreases due to diffusion limited contaminant transfer, the operation could become intermittent and would be optimized. The air flow rate (vacuum) concentrations of contaminant, oxygen, and carbon dioxide in the extracted air would be monitored regular. Additional sampling and analysis would also be conducted in order to meet the air emission permit requirements.

Several strategies can be used to determine the closeout of a SVE system. It is anticipated that the closeout would be determined based on the total mass removed from the subsurface and a cost-benefit analysis. For cost estimating, it is assumed that the SVE system would be operated for 10 years. A final soil sampling event may be conducted to verify and document the mass removal within the vadose zone treatment area.

<u>Treatment Performance Evaluation</u>
After the shutdown of the SVE system, soil samples would be collected within the treatment zone for VOC analysis to evaluate the effectiveness of the remedial action. For costing purposes, it is assumed that two soil borings would be advanced for soil sample collection.

<u>Institutional Controls</u>
Institutional controls (i.e., deed restriction) would be placed on the IDC facility such that any future activities would not damage the cap.

<u>Site Restoration</u>
After the completion of the remedial action, the soil vapor extraction wells and soil vapor monitoring points would be properly abandoned. All the air ducts and the SVE equipment would be removed or demobilized. The cap over the SVE treatment area would be properly repaired to meet specifications.

<u>Five-Year Review</u>
A five-year review would be conducted every five years using data obtained from the monitoring program. For this alternative, it is assumed that the review would be conducted for 30 years since residual contamination would remain.

4.3.2.3.2 Individual Evaluation of Alternative IDC-S3

<u>Overall Protection of Human Health and the Environment</u>
The combined cap and SVE system would minimize the overall contaminant mass that could migrate to groundwater because the SVE system would remove contaminant mass in the vadose zone hotspot to the extent practicable, and the cap would minimize infiltration of rainwater that could drive further contaminant migration. Direct contact risks with the contaminants at IDC are within EPA's acceptable

risk range. Installation of the vapor mitigation system would mitigate risks from vapor intrusion. This alternative would meet the RAO.

Compliance with ARARs

There are no Federal or Commonwealth chemical-specific ARARs for soil. This alternative would comply with EPA's soil vapor intrusion screening levels and location-specific and action-specific ARARs. An air permit would be attained, emissions would be regularly monitored, and health and safety measures would be performed to meet the federal and Commonwealth requirements during the pilot study and the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long Term Effectiveness and Permanence

Magnitude of Residual Risk - There are uncertainties regarding how effective unenhanced SVE would be in the clayey formation. Significant diffusion of contamination into the clay is likely to have occurred. Given the low permeability of the clay soils, the SVE system may not be effective at promoting back-diffusion and subsequent extraction to the aboveground treatment system. A pilot study would be conducted during the remedial design to collect site-specific parameters including air flow, and to reduce uncertainty in the full scale remedial action. If SVE is effective, then it would permanently reduce concentrations in the treatment zone. The cap, if maintained correctly, would be effective in reducing residual contaminant from migration in the vadose zone.

Adequacy of Controls – If effective, SVE would remove contaminant mass from the highly contaminated area and would reduce a significant portion of the contaminant mass. Capping and deed notice would provide adequate control of the residual contaminants if they are well-maintained and monitored. However, routine cap inspection and groundwater monitoring could be difficult to enforce over the long-term, which might results in inadequate control of site contamination.

Reliability of Controls – When properly design, SVE would be reliable in removing contaminant mass. In order for it to be effective over the long term, the cap would need to be regularly maintained. Over decades, residual contaminants under the cap may decrease due to volatilization and biodegradation, but might not be enough to meet PRGs.

Reduction of T/M/V Through Treatment

If effective, SVE would reduce T/M/V through treatment. The mass and volume of contaminants would be removed from the ground through the SVE operation. The contaminants would subsequently be adsorbed to the activated carbon and be destroyed during the carbon regeneration.

Short Term Effectiveness

This alternative would have some short-term impacts for several years or potentially more than 10 years, since the wells, piping and equipment associated with the remediation would occupy space on site, and the operation of a compressor would generate noise. Furthermore, the building would need to be modified for drill rig access. A health and safety plan would be developed, approved by EPA, and properly implemented. PPE and proper monitoring and emission control devices would be used. The impact to site workers is expected to be minimal. This alternative is not expected to result in short-term adverse impacts to the environment. The emission from the SVE system would meet the air permit requirements. IDW and used carbon would be properly disposed. It is estimated that this alternative would be operated for 10 years prior to shut down. During this period, the facility may not be suitable for residential use.

Implementability

The building would need to be modified; it is uncertain to what extent building modification is implementable. Experienced vendors could be procured and SVE equipment is commercially available. Due to the low permeable soil at the site, the achievable air flow rate induced by applied vacuum under natural conditions may be limited. Environmental fracturing, which is an innovative technology that still requires field improvement, would likely enhance performance of the SVE, but is not implementable at the site because fracturing in the shallow soils of the hotspot could damage buildings. A pilot study would be conducted to obtain site specific design parameters, such as the relationship between applied vacuum and air flow rates, to reduce the uncertainty during the remedial action.

Cost

The estimated capital cost for Alternative IDC-S3 $1,239,000. The estimated present worth of O&M and monitoring is $556,000. The total present worth is estimated to be $1,795,000.

4.3.3 Ramallo Soil Alternatives

4.3.3.1 Alternative R-S1 – No Action

4.3.3.1.1 Detailed Description of Alternative R-S1

The No Action alternative is retained for comparison purposes as required by the NCP. No remedial action would be implemented as part of this alternative. It does not include any institutional controls or monitoring program. Five-year reviews would be conducted by EPA to assess site conditions. No cost is included in the FS for five year reviews since it would be performed by EPA.

4.3.3.1.2 Individual Evaluation of Alternative R-S1

Alternative 1 is evaluated using the seven criteria discussed in Section 4.1.

Overall Protection of Human Health and the Environment

The site-specific HHRA indicates that risks to human health are above EPA's acceptable risk range due to inhalation of PCE. The No Action alternative would not eliminate any exposure pathways or reduce the level of human health risk of the existing contamination. It also would not provide protection to the environment. This alternative would rely on unmonitored natural attenuation processes to restore soil quality. Since the rate of restoration would be unknown, this alternative could not be considered protective of the environment. This alternative would not meet the RAOs.

Compliance with ARARs

This alternative would not achieve chemical-specific ARARs or PRGs. Location- and action-specific ARARs do not apply to this alternative since no remedial action would be conducted.

Long-Term Effectiveness and Permanence

This alternative would not be considered a permanent remedy since no action would be implemented to reduce the level of contamination or verify any naturally occurring reduction. It would not have long-term effectiveness. The potential for exposure of site receptors to contamination would not be eliminated. The level and migration of contaminants would not be monitored. Even though natural attenuation processes are occurring, the effectiveness of these natural attenuation processes in reducing the migration of contaminants would remain uncertain.

Reduction of T/M/V through Treatment

No reduction of contaminant T/M/V through treatment would be achieved under this alternative. The total volume of contaminated soil might increase if natural attenuation processes are unable to contain the existing mass. The extent and effectiveness of the toxicity reduction pathway, biodegradation of chlorinated contaminants, would be unknown.

Short-term Effectiveness

Since no remedial action would be implemented at the site, this alternative would not pose short-term risks to on-site workers or the community. It would not have adverse environmental impacts to habitat or vegetation at the site.

Implementability

This alternative could be implemented immediately since no services or permit equivalency would be required.

Cost

There are no capital or O&M costs associated with this alternative.

4.3.3.2 Alternative R-S2 –Containment

4.3.3.2.1 Detailed Description of Alternative R-S2

Under this alternative, a cap would be installed to cover the outdoor area of the Ramallo property. The purpose of the cap would be to reduce rainwater infiltration as much as possible through contaminated soils in this area. The existing building on site would also need to be retained to serve as an effective cap because it diverts rainwater from contaminated soil underlying the building. For cost estimating purposes, it is assumed that the cap to be installed would consist of concrete overlying the native clay soils or existing pavement. Figure 4-3 depicts the areas requiring capping. The components of this alternative are:

- Remedial design
- Cap Installation
- Cap Monitoring and Maintenance
- Five-year reviews

Remedial Design

Data obtained during the RI and pre-design investigation would be used to develop the design.

Cap Installation

Cap installation would be completed with widely available construction techniques and equipment. The cap would cover the outdoor area in and around the remediation target zone. Approximately six inches of concrete would be laid over the unpaved areas on the site. The cap would cover a surface area of approximately 5,000 square feet, which is anticipated to be larger than the remediation target zone in order to limit any horizontal infiltration of water. The cap would be engineered to limit any infiltration of rainwater into the contaminated soils, meaning that durable, low-permeability material would be used, and rainwater would be directed away from the remediation zone. It is assumed that installation would take place over approximately one month.

Cap Monitoring and Maintenance

The cap would require yearly inspection to look for cracks or other areas where water could seep through and into the soils. For costing purposes, it is assumed that maintenance would be needed every five years to seal cracks or replace deteriorated concrete.

Institutional Controls

Institutional controls (i.e., deed restrictions) would be placed on the Ramallo facility such that any future activities would not damage the cap.

Five-Year Review

A five-year review would be conducted every five years using data obtained from the monitoring program. For this alternative, it is assumed that the review would be conducted for 30 years.

4.3.3.2.2 Individual Evaluation of Alternative R-S2

Overall Protection of Human Health and the Environment

This alternative would provide conditional protection of the environment. The cap would be a barrier to direct exposure of contaminated soil to humans and biota. Data from the RI indicate that vadose zone contamination at Ramallo has impacted groundwater. While the cap would slow the mass flux of contamination from the vadose zone into the groundwater, it is unlikely to stop it completely. Furthermore, mass flux to groundwater could occur in the future if the cap is disturbed and precipitation is allowed to infiltrate into the contaminated soils. Installation of the vapor mitigation system would mitigate risks from vapor intrusion. This alternative would meet the RAOs in the soil target remediation zones.

Compliance with ARARs

There are no Federal or Commonwealth chemical-specific ARARs for soil. This alternative would comply with EPA's soil vapor intrusion screening levels and location-specific and action-specific ARARs. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-Term Effectiveness and Permanence

Magnitude of Residual Risk - This alternative could be effective in the long-term but may not provide a permanent remedy. The contamination would be left in place and potentially could continue to migrate to the underlying groundwater, though at a slower rate because of the cap. Due to the elevated concentrations of contaminants left in place, the land use would be limited. Any redevelopment would require additional remediation to be performed.

Adequacy of Controls - Capping and deed notices would provide adequate control of the contaminants left in place if the cap is well-maintained and monitored and deed notice is heeded. However, routine cap inspection and groundwater monitoring could be difficult to enforce over the long-term, which might results in inadequate control of site contamination.

Reliability of Controls - In order for it to be effective over the long term, the cap would need to be regularly maintained. Over decades, concentrations under the cap may decrease slightly due to volatilization and biodegradation, but not be enough to meet PRGs.

Reduction of T/M/V through Treatment

Capping should reduce the mobility of the contamination by limiting induced migration of contamination via rainwater percolation through the soil. Capping would not reduce toxicity or volume.

Short-term Effectiveness

This alternative would include limited site work and would cause minor impacts to the workers and surrounding buildings. Use of PPE by workers during remedial operations and sampling would minimize contaminant exposure.

Implementability

This alternative is technically implementable with available equipment, contractors, and materials in Puerto Rico. However, since maintenance and inspection are needed at the cap indefinitely, it is difficult to predict if these activities would be as regular as needed in the distant future.

Cost

The estimated capital cost for Alternative R-S2 is $299,000 including the remedial design. The estimated present worth of the annual O&M and monitoring is $70,000. The total present worth is estimated to be $369,000.

4.3.3.3 Alternative R-S3 –Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment

4.3.3.3.1 Detailed Description of Alternative R-S3

For this alternative, active treatment (soil vapor extraction enhanced by thermal heating) would be limited to soils in the area that is determined during the pre-design investigation to be a hotspot (i.e., principal threat waste area). Principal threat waste is estimated to be present across a surface area of 1,000 square feet to a depth of 80 feet. The most contaminated section would be excavated and disposed of off site; the remaining volume of soil in the hot spot would be treated with enhanced soil vapor extraction, and the remaining area of the site would be capped. This remedial alternative consists of the following major components:

- Pre-design investigation and remedial design
- Excavation and off-site disposal
- Soil vapor extraction and thermal treatment system installation
- Operations and decommissioning
- Treatment performance evaluation
- Cap Installation

- Institutional controls
- Site restoration
- Five-year review

Soil Excavation and Off-Site Disposal

Elevated PCE concentrations that exceed the principal threat waste criterion of 166 mg/kg were detected at the surface at RMSB-18. Since the SVE treatment would target the subsurface zone, this surface soil contamination would be excavated and disposed of off-site in a RCRA Subtitle C landfill. For costing purposes, an area approximately 10 feet by 10 feet by 4 feet deep (approximately 15 cubic yards) would be excavated, containerized, and shipped off-site for disposal. The exact dimensions and volume of soil to be excavated would be determined during the remedial design. Figure 4-4 shows the approximately area to be excavated.

Soil Vapor Extraction and Thermal Treatment System Installation and Operation

Combined vertical soil vapor extraction and heating wells would be installed. Enhanced SVE treatment would target the hotspot (i.e., principal threat waste area). ERH and TCH are the most common methods for thermal remediation of chlorinated solvent contamination. Both ERH and TCH are anticipated to be effective at the site. For costing purposes, it is assumed that ERH will be used. Combined heating and vapor extraction wells would be installed on 20 foot centers across the hotspot. A temperature monitoring well would be installed to monitor the progress of heating in the soil, along with two additional dedicated soil vapor extraction wells. Figure 4-4 shows the approximate areas targeted for SVE treatment.

The heated vapors extracted from the SVE wells would first be passed through a knockout tank, where most of the moisture is cooled down to ambient temperature and separated. The remaining vapors are passed through a refrigerated heat exchanger system where the vapors are further cooled, thus condensing the chemical constituents in the vapor. Any remaining vapors are passed through regenerative carbon adsorbers that remove any remaining fugitive VOCs prior to discharge into the atmosphere. The water recovered from the knockout tank would either be treated with carbon and discharged or disposed of at an appropriate off-site facility. The condensate recovered from the heat exchanger system would be disposed of at an appropriate off-site facility. The existing pavement at the site would be retained since it serves to inhibit both heat and vapor loss from the subsurface.

Heating of the soils is anticipated to take approximately 100 days, during which the SVE system would be operated to remove volatilized contaminants. The air flow rate (vacuum) concentrations of contaminant, oxygen, and carbon dioxide in the extracted air would be monitored regularly. Additional sampling and analysis would also be conducted in order to meet the air emission permit requirements. After heating, an approximately 100 day soil cool down period would be needed prior to removal of the system and abandonment of the wells.

Treatment Performance Evaluation

After the heating period, soil samples would be collected within the treatment zone for VOC analysis to evaluate the effectiveness of the remedial action. For costing purposes, it is assumed that eight soil borings would be advanced for soil sample collection.

Contaminants at low concentrations would likely remain in the vadose zone.

Cap Installation

Cap installation would be completed with widely available construction equipment as described in Alternative R-S2. In order to limit any horizontal infiltration of rainwater into the contaminated soils, the cap would extend well beyond the remediation target zone and encompass all the outdoor areas of the Ramallo property. It is assumed that installation would take place over approximately one month. Figure 4-4 shows the approximately areas target for capping.

Institutional Controls

Institutional controls (i.e., deed restriction) would be placed on the Ramallo facility such that any future activities would not damage the cap.

Site Restoration

After the completion of the remedial action, the soil vapor extraction wells and soil vapor monitoring points would be properly abandoned. All the air ducts and the SVE equipment would be removed or demobilized. The building slab and cap would be properly repaired to meet specifications.

Five-Year Review

A five-year review would be conducted every five years using data obtained from the monitoring program. For this alternative, it is assumed that the review would be conducted for 30 years since residual contamination would remain.

4.3.3.3.2 Individual Evaluation of Alternative R-S3

Overall Protection of Human Health and the Environment

The combined excavation and off-site disposal, SVE and thermal treatment, and capping would prevent the direct contact risks for future workers and residents, and would minimize the overall contaminant mass that could migrate to groundwater because the SVE and thermal treatment system would remove contaminant mass in the vadose zone to the extent practicable, and the cap would minimize infiltration of rainwater that could drive further contaminant migration. Installation of the vapor mitigation system would mitigate risks from vapor intrusion. This alternative would achieve the RAO.

Compliance with ARARs

There are no Federal or Commonwealth chemical-specific ARARs for soil. This alternative would comply with EPA's vapor intrusion screening levels, and location-specific and action-specific ARARs. An air permit would be attained, emissions would be regularly monitored, and health and safety measures would be performed to meet the federal and Commonwealth requirements during the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long Term Effectiveness and Permanence

Magnitude of Residual Risk - This alternative would provide long-term effectiveness and permanence for vadose zone soil and would increase the likelihood of success for remediation. The hotspot would be either excavated and disposed off-site or treated with SVE and thermal treatment. Heating of the clayey vadose zone is expected to remove significant mass of contamination from the clay. The cap, if maintained correctly, would reduce further contaminant migration in the vadose zone.

Adequacy of Controls – Excavation and off-site disposal is not reversible. SVE and thermal treatment would remove contaminant mass from the highly contaminated area and would reduce a significant portion of the contaminant mass. Capping and deed notices would provide adequate control of the residual contaminants if they are well-maintained and monitored. However, routine cap inspection and groundwater monitoring could be difficult to enforce over the long-term, which might result in inadequate control of site contamination.

Reliability of Controls – When properly designed, SVE and thermal treatment would be reliable in removing contaminant mass. In order for it to be effective over the long term, the cap would need to be regularly maintained. Over decades, residual contaminants under the cap may decrease due to volatilization and biodegradation, but might not be enough to meet PRGs.

Reduction of T/M/V Through Treatment

SVE and thermal treatment would reduce T/M/V through treatment. Contaminants would be removed from the ground through excavation and operation of the in situ thermal remediation and SVE system. The contaminants would be removed from the extracted vapor stream with activated carbon or condensation and either be destroyed during the carbon regeneration or disposed of off-site.

Short Term Effectiveness

This alternative would have some short-term impacts for approximately one year because of the operation of the heating and SVE system. The operation of a compressor would generate noise. A health and safety plan would be developed, approved by EPA, and properly implemented. PPE and proper monitoring and emission control devices would be used. The impact to site workers is expected to be minimal. This alternative is not expected to result in short-term adverse impact to the environment. The emission from the SVE system would meet the air permit requirements. IDW, condensate, and used carbon would be properly disposed.

Implementability

Excavated hazardous waste would need to be disposed in a RCRA Subtitle C landfill, which is lacking in Puerto Rico. The waste would need to be containerized and shipped to the US mainland. For the excavation, SVE, and thermal treatment, experienced vendors could be procured and thermal remediation and SVE equipment is commercially available.

Cost

The estimated capital for Alternative R-S3 is $3,664,000. The estimated present worth of annual O&M and monitoring is $70,000. The total present worth is estimated to be $3,734,000.

4.3.3.4 Alternative R-S4 – In Situ Treatment and Containment

4.3.3.4.1 Detailed Description of Alternative R- S4

Under this alternative, the hotspot (i.e., principal threat waste area) would be treated using in situ treatment. The remaining contaminated soils would be capped. Figure 4-5 shows the approximate areas for treatment and capping. The in situ treatment area covers approximately 1,000 square feet, and capping would cover approximately 5,000 square feet. Alternative R-S4 consists of the following activities:

- Treatability study
- Remedial design
- Emplacement of amendment
- Capping
- Institutional controls
- Five-year reviews

Bench Scale Study

Although a combined ISCR/bioremediation amendment is discussed herein for cost estimating purposes, a bench scale treatability study is recommended to identify the most cost-effective amendment to be emplaced in the soil. The bench study would also determine dosing parameters for the amendment.

Remedial Design

Data obtained during the RI, pre-design investigation, and bench scale study would be used to develop the design. The scope of the amendment emplacement would be determined after the pre-design investigation further delineates the contamination.

Emplacement of Amendment

Several types of amendments and amendment delivery processes have been identified, evaluated, and retained in Section 2. All retained process options would be considered and the most cost effective amendment and delivery process would be selected during the design phase. For alternative development and cost estimating purposes, boreholes would be installed across the site on 30 foot centers from a depth of ten feet bgs to the depth of contamination (80 feet), and amendment would be introduced using hydraulic fracturing. Hydraulic fracturing vendors prefer not to fracture in the top ten feet to avoid damage to buildings and calibrated equipment. An amendment concentration of 0.005 pound amendment per pound of soil would be targeted. It is assumed that the fracturing and emplacement would take place over approximately 5 weeks. For the surface contamination around RMSB-18, an area of approximately 100 square feet by 4 feet deep, the amendment would be mixed in with the contaminated soil using mechanical mixing. Multiple treatments of the soil would be required. For costing purposes, two rounds of treatment would be assumed, the first round would include the full area and the second would only include half the area.

Capping

A cap would be installed and maintained as described in Alternative R-S2.

Institutional Controls

Institutional controls (i.e., deed restrictions) would be placed on the Ramallo facility such that any future activities would not damage the cap.

Five-Year Review

A five-year review would be conducted every five years using data obtained from the monitoring program. For this alternative, it is assumed that the review would be conducted for 30 years since residual contamination would remain.

4.3.3.4.2 Individual Evaluation of Alternative R- S4

Overall Protection of Human Health and the Environment

This alternative would provide protection of human health and the environment by destroying contaminants by in situ treatment (i.e., biological or abiotic mechanisms). Since a cap would be installed over the site, the remaining contaminant concentrations would be expected to decrease very slowly over time due to volatilization and limited biodegradation. Installation of the vapor mitigation system would mitigate risks from vapor intrusion. This alternative would meet RAOs.

Compliance with ARARs

There are no applicable Federal or commonwealth chemical-specific ARARs for the soil. This alternative is designed to reduce contaminant concentrations in the soil. In situ chemical treatment should reduce concentrations substantially. However, given the clay matrix, it may prove difficult to achieve the PRGs. The cap would not reduce concentrations and would not achieve PRGs.

This alternative would comply with EPA's vapor intrusion screening levels and location-specific and action-specific ARARs. An air permit would be attained, emissions would be regularly monitored, and health and safety measures would be performed to meet the federal and Commonwealth requirements during the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-term Effectiveness and Permanence

Magnitude of Residual Risk – This alternative would be effective in the long-term and would be permanent. The contamination would be remediated by conducting multiple fractures and injections across both the areal and the vertical extent of the treatment zone, and injecting a long-lived amendment. Contaminants would be permanently destroyed.

The cap would be installed to cover the residual contamination and to minimize rainwater infiltration. In order for it to be effective over the long term, the cap would need to be regularly maintained. Over decades, concentrations under the cap may decrease slightly due to volatilization and biodegradation, but not be enough to meet PRGs.

Adequacy of Controls – In situ treatment would remove contaminant mass from the highly contaminated hotspot and would reduce contaminant mass. Since contaminants have migrated into the pore matrix of the clayey soil, it is uncertain how much of the contaminant mass would be removed. Capping and deed notice would provide adequate control of the residual contaminants if the cap is well-maintained and monitored and deed notice is heeded. However, routine cap inspection and groundwater monitoring could be difficult to enforce over the long-term, which might result in inadequate control of site contamination.

Reliability of Controls – When designed and implemented properly, in situ treatment would be reliable in removing contaminant mass. The clayey soil would make it difficult for this treatment to attain significant mass reduction. In order for it to be effective over the long term, the cap would need to be regularly maintained.

Reduction of Toxicity, Mobility or Volume through Treatment

In-situ treatment would reduce the toxicity and volume of contamination in the treatment zone. Chlorinated VOCs would be transformed to ethene, ethane, and carbon dioxide. Since emplacement of the amendment would be by fracturing, and fracturing increases the porosity of the subsurface, there is the possibility that mobility of the contamination would increase. However, under this alternative the fractures would be filled with amendment and become reactive zones; thus the purpose of increasing porosity in the subsurface is to open more pathways for contaminant destruction, and not for increasing mobility. Capping would not decrease toxicity and volume of the contaminant but it would reduce the mobility of the contamination by hindering rainwater infiltration.

Short-term Effectiveness

This alternative would include substantial site work and would cause significant impacts to the workers and surrounding communities during the amendment emplacement phase and excavation phase. Use of PPE by workers during activities would minimize contaminant exposure. Multiple rounds of treatment would be required. It is expected that treatment would be completed in 5 years.

Implementability

The fracturing, mechanical mixing, and emplacement components are technically implementable. The processes that govern degradation reactions are well understood, and technical feasibility of biological and abiotic remediation has been established at numerous sites. Despite this, bioremediation and abiotic remediation are still considered innovative technologies. They would require bench and pilot scale testing prior to implementation. The technical difficulty for the implementation of this technology at this site is the treatment in the clayey soil matrix, which makes distribution of the amendment and contact with the contaminants difficult. No difficulty in obtaining a permit for the emplacement of amendments is anticipated. Existing site operations and infrastructure may inhibit the optimal layout of the remediation system.

Capping the site soils is implementable. Since the cap would need to be maintained in perpetuity, it is uncertain if maintenance over the long term is implementable.

Cost

The total present worth for Alternative R-S4 is $1,855,000. The estimated capital cost is $1,785,000 and the monitoring cost over 30 years is $70,000. Detailed cost estimates are presented in Appendix A.

4.3.4 Groundwater Alternatives

4.3.4.1 Alternative GW1 – No Action

4.3.4.1.1 Detailed Description of Alternative GW1

The No Action alternative is retained for comparison purposes as required by the NCP. No remedial action in groundwater would be implemented as part of this alternative. It does not include any institutional controls or monitoring program. Five-year reviews would be conducted by EPA to assess site conditions. No cost is included in the FS for five year reviews.

4.3.4.1.2 Individual Evaluation of Alternative GW1

Overall Protection of Human Health and the Environment

The No Action alternative would not eliminate any exposure pathways or reduce the level of human health risk of the existing groundwater contamination. It also would not provide protection to human health. This alternative would rely on unmonitored natural attenuation processes to restore groundwater quality. Since the rate of restoration would be unknown, this alternative cannot be considered protective of the environment or human health. This alternative would not meet the RAOs.

Compliance with ARARs

This alternative would not achieve chemical-specific ARARs established for groundwater. Location- and action-specific ARARs do not apply to this alternative since no remedial action would be conducted.

Long-Term Effectiveness and Permanence

This alternative would not be considered a permanent remedy since no action would be implemented to reduce the level of contamination or verify any naturally occurring attenuation. It would not have long-term effectiveness. The potential for exposure to contaminated groundwater to site receptors would not be eliminated. The level and migration of contaminants would not be monitored. Even though natural attenuation processes are occurring, the effectiveness of these natural attenuation processes in reducing the migration of contaminants would remain uncertain.

Reduction of T/M/V through Treatment

No reduction of contaminant T/M/V through treatment would be achieved under this alternative. The total volume of contaminated groundwater might increase if natural attenuation processes are unable to contain the plume. The extent and effectiveness of the toxicity reduction pathway, biodegradation of chlorinated contaminants, would be unknown.

Short-term Effectiveness

Since no remedial action would be implemented at the site, this alternative would not pose short-term risks to on-site workers or the community. It would not have adverse environmental impacts to habitat or vegetation at the site.

Implementability

This alternative could be implemented immediately since no services or permit equivalency would be required.

Cost

There are no capital or O&M costs associated with this alternative.

4.3.4.2 Alternative GW2 – Groundwater Extraction, Treatment, and Long-term Monitoring

4.3.4.2.1 Detailed Description of Alternative GW2

Based upon existing data, the groundwater contamination appears to be predominantly situated in the saprolite which corresponds to an approximately 50-foot interval between the upper silty clay and the bedrock. There is contamination detected in the bedrock; however, the amount of groundwater data obtained from the bedrock aquifer is notably limited, lending some uncertainty as to the extent of the bedrock contamination. There is also very limited hydraulic data within the saprolite and the bedrock. This serves as the basis for the alternative described below and alternative GW3.

In addition to the common elements described in Section 4.3.1.2, Alternative GW2 consists of the following activities:

- Groundwater modeling
- Remedial design
- Groundwater extraction wells
- Ex situ treatment system installation and operation, and performance monitoring
- Discharge of treated groundwater
- Operation and maintenance
- Long-term monitoring
- Five-year reviews

Groundwater Modeling

Data obtained during the RI and pre-design investigation would be used to develop a groundwater model to aid in the development of the design. Numerical groundwater modeling would be conducted to establish the extraction well locations and the optimal pumping rates.

Remedial Design

The scope of the extraction and treatment system would be determined after the pre-design investigation further delineates the contamination and provides groundwater flow data. A remedial design would be prepared to specify the design details of the extraction and treatment systems.

Groundwater Extraction Wells

Using the limited extent of hydrogeologic characterization and groundwater data currently available for this site, a preliminary groundwater model was constructed. For cost estimating purposes, the simple model used Darcy's Law, the RI report's water levels and groundwater gradient information, the highest specific capacity from the available data, and the plume's lateral extent which is estimated to be 406,400 square feet to develop the basis for selection of a total flow rate, the number of pumping wells needed, and preliminary estimates regarding well locations.

Based upon the results of this model, the use of four extraction wells (two near the source area and two downgradient near the 5 µg/L isocontour) was considered for this alternative, as shown in Figure 4-6. It is estimated that 30 gallons per minute (gpm) of pumping from each well location (for a total flow of 120 gpm) would be necessary to efficiently achieve and maintain hydraulic control during operation, thereby preventing high levels of contamination from migrating further downgradient. The wells would each be screened throughout the saprolite layer and in the shallow portion of the bedrock such that known contaminated groundwater in the bedrock would also be captured. It is assumed that contaminated bedrock groundwater that is beyond the capture zone of the extraction well system would be allowed to continue migrating and attenuating. This extraction well configuration is considered to be conservative, as it targets the entire depth of the saprolite and the bedrock aquifer across the extent of the groundwater plume. Assuming it would take three days to drill and three days to develop an extraction well, it is estimated that drilling and constructing the wells would take approximately five weeks.

The contaminated groundwater would be treated ex situ in the groundwater treatment system.

Ex situ Treatment System Installation and Operation, and Performance Monitoring

For the purposes of this FS, it is assumed that the treatment train would consist of the following steps from start to finish: 1) influent flow equalization, 2) bag filtration, 3) air stripping, 4) off-gas treatment with granular activated carbon, and 5) off-gas treatment with potassium permanganate. The groundwater treatment system would be sized for an operating flow rate of 120 gpm.

The function of each of the process steps is described below.

- The equalization tank would serve to stabilize the combined influent flow rate and water quality to the treatment plant, so that consistent operational settings can be generally maintained for treatment. The tank would also allow some settling of suspended solids, such as iron particulates that are generated via oxidation following groundwater extraction. Air may also be diffused into the tank to aid in oxidizing the ferrous iron to be filtered out in the bag filters in the next treatment step. The water would be conveyed from the tank through the remaining unit processes via transfer pump.

- Bag filters (configured in two by two series in parallel operation) would serve to remove suspended solids from the groundwater influent before entering subsequent treatment unit processes. The bag filters would require periodic removal and disposal when they become full of particulates. This step is intended to reduce O&M requirements associated with the air stripping, as described below, as well as to meet surface water discharge requirements.

- Air strippers (e.g., low profile, removable tray type) would serve to reduce groundwater VOC concentrations to levels acceptable for surface water discharge.

- Vapor phase granular activated carbon units would remove the heavier, more sorptive VOCs: PCE and TCE. Series arrangement of the GAC units would allow continuous system operation during unit change out. When unacceptable breakthrough occurs at the lead unit, it would be bypassed, changed out, and brought back on line as the secondary unit in series.

- The potassium permanganate unit would primarily serve to remove cis-1,2-DCE and vinyl chloride via chemical oxidation, as these chemicals are not sorptive and would not be removed using GAC. The treated air effluent would then be discharged to ambient air through a stack.

The presence of soluble iron in the groundwater can possibly lead to iron fouling. In 14 samples for iron in the saprolite, the mean concentration was 2.5 mg/L with a standard deviation of 4.7 mg/L. Assuming that these are measurements of soluble iron, these concentrations indicate that iron fouling is possible. While chances of iron fouling are low with this concentration, if necessary, it is assumed that a polyphosphate based metals sequesterant could be added as a chemical feed to the influent flow equalization tank to prevent dissolved iron from precipitating and accumulating as scale on the pumps, interior walls of the process piping, and air stripper trays.

Installation and startup time for the treatment system is assumed to be approximately 22 weeks. During the design phase, treatment processes should be evaluated as well as sizing of the treatment vessels. It is assumed that this alternative would be implemented for longer than 30 years.

Discharge of Treated Groundwater

Following the treatment step, the treated groundwater would be sampled periodically prior to discharge to verify compliance with permit requirements. For costing purposes, off-site surface water discharge to the Rio Arroyata was assumed. Treated water would be pumped via an above ground discharge line to a location on the Rio Arroyata that is most easily accessible from the treatment plant. Rip rap would be placed at the outfall of the discharge pipe to help mitigate damage to creek banks from the discharge.

Operation and Maintenance

System maintenance that includes maintenance of the wells, pumps, and treatment process equipment would be conducted as required during the operation of the groundwater pump and treat system. Treatment performance monitoring would include collection of groundwater samples from locations upgradient and downgradient of the plume. Results from the monitoring program would be used to evaluate the performance and to adjust operating parameters for the extraction system, as necessary. Periodic samples would be collected from various sample locations along the groundwater treatment train to verify the effectiveness of each treatment process. Effluent samples would be collected to verify compliance with Puerto Rico surface water discharge requirements.

Long-term Monitoring

A long-term groundwater monitoring program would be instituted to collect data on contaminant concentrations and movement on and off site. For costing purposes, it is assumed that 16 existing monitoring wells and 4 new monitoring wells added during the pre-design investigation would be used for the monitoring program. The monitoring data collected would be evaluated and used to assess the migration and attenuation of the groundwater contamination and to identify the need for any further remedial action.

Five-Year Review

Five year reviews would be conducted by EPA to assess the ongoing risks to human health and the environment posed by the site. The evaluations would be based on the data collected from groundwater monitoring.

4.3.4.2.2 Individual Evaluation of Alternative GW2

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by the active pumping and treatment of contaminated groundwater. It is expected that the pumping would reduce the plume size and contaminant concentration in the aqueous phase. Currently, there are no risks to human health as the public supply wells have been shut down. Institutional controls would prevent potential future human exposure to groundwater contamination.

Compliance with ARARs

Contaminant concentrations in the groundwater are expected to decrease over time. It is anticipated that the contaminant concentrations would drop rapidly at the beginning and reduce asymptotically after a certain period of pumping. Long-term groundwater monitoring would be conducted to monitor reductions in the contaminant concentrations over time. This alternative would be designed to comply with location- and action- specific ARARs. Both air and treated water discharge permits would be obtained, emissions and water effluence would be regularly monitored to ensure permit requirements are met, and health and safety measures would be performed to meet the federal and Commonwealth requirements during the pilot study and the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-term Effectiveness and Permanence

Magnitude of Residual Risk - This alternative would have long-term effectiveness and permanence. Currently, the saprolite and bedrock aquifers are contaminated. Pumping would extract contaminants from both the saprolite and bedrock aquifers and also limit downgradient migration of the contaminants. However, because of matrix diffusion effects and also potential migration of contaminants from the vadose zone serving as a continuing source, it is expected that contaminant concentrations would drop rapidly at the beginning and reduce asymptotically after a certain period of pumping. Long-term groundwater monitoring would be implemented to monitor groundwater concentrations over time.

Adequacy of Controls – This alternative would provide adequate control of current human health risk. Institutional controls would be enforced so that no new drinking water wells are drilled in the affected area. Pumping and treatment would be considered effective in removing the contaminant plume as it has been demonstrated at other sites. However, the extraction wells may not intercept all of the contaminant flow, thus allowing some contaminants to migrate downgradient, possibly into the Rio Arroyata. The effectiveness and adequacy of controls of the alternative would be confirmed through groundwater monitoring.

Reliability of Controls – Pumping and treatment is a proven reliable technology. Institutional controls, if properly enforced, would be considered reasonably adequate and reliable for protection of human health. The long-term effectiveness of this alternative would be assessed through routine groundwater and surface water monitoring and five-year reviews. As part of the monitoring program, groundwater would be sampled to monitor groundwater quality over time to verify that contaminant concentrations would not be increasing over time or posing an unacceptable risk to human health and the environment.

Reduction of T/M/V through Treatment

This alternative would reduce the T/M/V of the contaminant plume through groundwater extraction and treatment.

Short-term Effectiveness

Limited site work and installation of the extraction wells, piping and the groundwater treatment system would be performed without significant impact to the community and workers. Site workers would follow approved health and safety plans and would wear appropriate PPE to minimize exposure to contamination and also protection from physical hazards. No adverse impacts to habitats or vegetation would be anticipated from activities associated with implementation of this alternative.

The extraction wells and treatment plant would require one year to complete and the O&M of the system would be much longer than 30 years, which is the default evaluation period for the FS.

Implementability

Pumping and treatment is a proven technology and would be implementable. Many vendors are available to provide the required equipment and services. All required permits would be obtained. Institutional controls and long-term monitoring could be implemented by the Commonwealth.

Cost

The total present worth for Alternative GW2 is $9,421,000. The estimated capital cost is $3,032,000, and the O&M and monitoring cost 30 years is $6,389,000. Detailed cost estimates are presented in Appendix A.

4.3.4.3 Alternative GW3 – Focused Groundwater Extraction, Treatment, and Long-term Monitoring

4.3.4.3.1 Detailed Description of Alternative GW3

In additional to the common elements described in Section 4.3.1.2, Alternative GW3 consists of the following activities:

- Groundwater modeling
- Remedial design
- Installation of groundwater extraction wells and submersible pumps
- Ex situ treatment system installation and operation, and performance monitoring
- Discharge of treated groundwater
- Operation and maintenance
- Long-term monitoring
- Five-year reviews

Groundwater Modeling

Data obtained during the RI and pre-design investigation would be used to develop a numerical groundwater model to aid in the development of the design. The main differences between this alternative and Alternative GW2 is the extraction under this alternative would focus on the more contaminated area of the plume. Under this alternative, one extraction well would be place near the source area and one extraction well would be placed in a location within the downgradient plume area to be determined using the numerical groundwater model. Groundwater modeling would be conducted to determine the optimal locations for the two extraction wells and the required pumping rate to efficiently capture the contaminated groundwater. This would allow achieving the RAOs at less cost.

Remedial Design

The scope of the extraction and treatment system would be determined after the pre-design investigation further delineates the contamination and provides groundwater flow data. A remedial design would be prepared to specify the design details of the extraction and treatment systems.

Groundwater Extraction Wells

Using the same preliminary groundwater model described in Section 4.3.4.2.1 for Alternative GW2 and a focused lateral extent of the plume estimated to be approximately 173,000 square feet, the basis for total flow rate, the number of pumping wells needed, and preliminary considerations regarding well locations were developed.

Based upon the results of this model, the use of two extraction wells (one near the source area and one downgradient near the end of the focused plume extent) was considered for this alternative, as shown in Figure 4-7. It is estimated that 30 gpm of pumping from each well location (for a total flow of 60 gpm - half of the total flow rate for GW2) would be necessary to efficiently achieve and maintain hydraulic control during operation, thereby preventing high levels of contamination from migrating further downgradient. The wells would each be screened throughout the saprolite layer and in the shallow portion of the bedrock such that known contaminated groundwater in the bedrock would also be captured. It is assumed that contaminated saprolite and bedrock groundwater that is beyond the capture zone of the extraction well system would be allowed to continue migrating and attenuating. Long-term groundwater monitoring would be conducted to monitor contaminant concentrations over time. Assuming it would take three days to drill and three days to develop an extraction well, it is estimated that drilling and constructing the wells will take approximately two and a half weeks.

The contaminated groundwater would be treated ex situ in the groundwater treatment system.

Ex situ Treatment System Installation and Operation, and Performance Monitoring

For the purpose of this FS, it is assumed that the treatment train would consist of the same steps as described under Alternative GW2. However, the groundwater treatment system for this alternative would be sized for an operating flow rate of 60 gpm (as opposed to 120 gpm).

Installation and startup time for the treatment system is also assumed to be approximately 22 weeks. During the design phase, treatment processes should be evaluated as well as sizing of the treatment vessels. It is assumed that this alternative would be implemented for longer than 30 years.

Discharge of Treated Groundwater

Discharge of treated groundwater would be implemented as described under Alternative GW2.

Operation and Maintenance

Operation and maintenance would be implemented as described under Alternative GW2.

Long-term Monitoring

Long-term monitoring would be implemented as described under Alternative GW2.

Five-Year Review

Operation and maintenance would be implemented as described under Alternative GW2.

4.3.4.3.2 Individual Evaluation of Alternative GW3

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by the active pumping and treatment of contaminated groundwater. It is expected that the pumping would reduce the plume size and contaminant concentration in the aqueous phase. Currently, there are no risks to human health as the public supply wells have been shut down. Institutional controls would prevent potential future human exposure to groundwater contamination. This alternative would achieve the RAOs.

Compliance with ARARs

Contaminant concentrations in the groundwater are expected to decrease over time. It is anticipated that the contaminant concentrations would drop rapidly at the beginning of the groundwater extraction and reduce asymptotically after a certain period of pumping. Long-term groundwater monitoring would be conducted to monitor the contaminant concentrations over time.

This alternative would be designed to comply with location- and action- specific ARARs. Both air and treated groundwater discharge permits would be obtained, emissions and treated water would be regularly monitored, and health and safety measures would be performed to meet the federal and Commonwealth requirements during the pilot study and the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-term Effectiveness and Permanence

Magnitude of Residual Risk - This alternative would have long-term effectiveness and permanence. Currently, the saprolite and bedrock aquifers are contaminated. Extraction and treatment of contaminated groundwater would extract contaminants from both the saprolite and bedrock aquifers and also limit downgradient migration of the contaminants. However, because of matrix diffusion effects and also potential migration of contaminants from the vadose zone, it is expected that contaminant concentrations would drop rapidly at the beginning of treatment and would reduce asymptotically after a certain period of pumping. Long-term groundwater monitoring would be implemented to monitor the groundwater concentrations over time.

Adequacy of Controls – This alternative would provide adequate control of human health risk. Institutional controls would be enforced so that no new drinking water wells are drilled in the affected area. Pumping and treatment would be considered effective in removing the contaminant plume as it has been demonstrated at other sites. However, the extraction wells may not intercept all of the contaminant flow, thus allowing some contaminants to migrate downgradient, possibly into the Rio

Arroyata. The effectiveness and adequacy of controls of the alternative would be confirmed through groundwater monitoring.

Reliability of Controls – Pumping and treatment is a proven, reliable technology. Institutional controls, if properly enforced, would be considered reasonably adequate and reliable for protection of human health. The long-term effectiveness of this alternative would be assessed through routine groundwater and surface water monitoring and five-year reviews. As part of the monitoring program, groundwater would be sampled to monitor groundwater quality over time to verify that contaminant concentrations would not be increasing over time or posing an unacceptable risk to human health and the environment.

Reduction of T/M/V through Treatment
This alternative would reduce the T/M/V of the contaminant plume through groundwater extraction and treatment.

Short-term Effectiveness
Limited site work and installation of the extraction wells, piping and the groundwater treatment system would be performed without significant impact to the community and workers. Site workers would follow approved health and safety plans and would wear appropriate PPE to minimize exposure to contamination and also protection from physical hazards. No adverse impacts to habitats or vegetation would be anticipated from activities associated with implementation of this alternative.

The extraction wells and treatment plant would require one year to complete and the operation and maintenance of the system would be much longer than 30 years, which is the default evaluation period for the FS.

Implementability
Pumping and treatment is a proven technology and would be implementable. Many vendors are available to provide the required equipment and services. All required permit would be obtained. Institutional controls and long-term monitoring could be implemented by the Commonwealth.

Cost
The total present worth for Alternative GW3 is $8,881,000. The estimated capital cost is $2,715,000, and the monitoring cost over 30 years is $6,166,000. Detailed cost estimates are presented in Appendix A.

4.3.4.4 Alternative GW4 – In situ Treatment and Long-term Monitoring

4.3.4.4.1 Detailed Description of Alternative GW4

Under this alternative, in situ treatment would be implemented in the saprolite within a focused isocontour that would be determined after the pre-design investigation. For cost estimating purposes, it is assumed that chemical oxidant would be injected inside the 1,000 µg/L PCE isocontour in the saprolite. If determined necessary based on numerical groundwater modeling results during the remedial design phase, a permeable barrier containing ZVI would be emplaced using fracturing at the downgradient edge of the PCE plume in the saprolite. Figure 4-8 depicts the conceptual layout of the alternative. Long-term monitoring would be conducted outside the treatments areas. In addition to the common elements described in Section 4.3.1.2, Alternative GW4 consists of the following activities:

- Groundwater modeling
- Bench scale treatability study
- Remedial design
- ISCO injections and ZVI emplacement
- Long-term monitoring
- Five-year reviews

Groundwater Modeling

Numerical groundwater modeling would be conducted after the pre-design investigation. It would be developed to calculate the optimal locations for implementing the in situ treatment and to determine if a PRB is necessary to remediate the PCE plume downgradient of the in situ treatment area.

Treatability Study

Although an ISCO amendment (activated persulfate) and ZVI are discussed herein for cost estimating purposes, a bench scale treatability study is recommended to identify the most cost-effective amendments for this alternative. The bench study would also determine dosing parameters for the amendment.

Remedial Design

Data obtained during the RI, pre-design investigation, and bench scale study would be used to develop the design. The scope of the amendment injection and emplacement would be determined after the pre-design investigation further delineates the contamination. A performance based design would be prepared to specify the objectives and final end points of the treatment rather than the treatment process.

ISCO Injections and ZVI emplacement

For cost estimating purposes, it is assumed that ISCO injections in the saprolite would be installed on 15 foot centers in the treatment zone to a depth of 150 feet. For costing purposes, it is assumed the treatment zone is approximately 2,500 square feet. This corresponds to 15 injection points. For alternative development purposes, activated persulfate would be injected along with an iron activator, a pH adjustment chemical, and a hydrogen peroxide activator. The mass of each component was calculated using a saprolite total pore volume of 32,075 cubic feet and an amendment ratio of 0.41. The injection point installation is estimated to take about 10 weeks. The subsequent three rounds of injection are estimated to take five and a half weeks each for the first two rounds and two weeks for the third round. Total construction and operations time for the in situ treatment is estimated to take 23 weeks with the first round of injections occurring during drilling activities.

For costing purposes, it is assumed a PRB is necessary. A PRB 250 feet long with nine injection points extended down to 150 feet bgs would be installed in the downgradient portion of the PCE plume. The location of the PRB would be determined during the design phase based on groundwater modeling. For costing purposes, ZVI would be used to form the PRB. The amount of amendment required was calculated by estimating the mass of soil in the treatment zone and taking a ratio of amendment to soil (0.27%). For costing purposes, it is assumed that the PRB would need replacement every 10 years. Therefore, three future replacements would be budgeted for year 10, year 20, and year 30 for a 30 year operation period, which is the default duration for the FS. The PRB would need to be in place for a much longer period. It is assumed that the total construction time for the PRB would be eight weeks.

It is assumed that the injection and emplacement would take place over approximately 4 months. It is expected that multiple rounds of injection would be required to treat the contaminated groundwater in the treatment zone. The PRB would need to be maintained for a long period of time until the groundwater has reached the PRGs. Monitoring would be conducted after treatment to ensure that RAOs had been met within the injection zone and to monitor performance of the reactive barrier.

Long-term monitoring
Long-term monitoring would be implemented as described in Alternative GW2.

Five-Year Review
Five year reviews would be conducted by EPA to assess the ongoing risks to human health and the environment posed by the site. The evaluations would be based on the data collected from groundwater monitoring.

4.3.4.4.2 Individual Evaluation of Alternative GW4

Overall Protection of Human Health and the Environment
This alternative would provide protection of human health and conditional protection of the environment. By applying in situ treatment in the form of injections and a PRB, if necessary, the treatment would reduce the plume size and contaminant concentration. Currently, in the bedrock, there are no risks to human health as the public supply wells have been shut down. Institutional controls would prevent potential future human exposure to groundwater contamination.

Compliance with ARARs
Contaminant concentrations in the groundwater are expected to decrease over time. It is anticipated that the PRGs would not be met through the treatment. Long-term groundwater monitoring would be conducted to monitor the contaminant concentrations over time.

This alternative would be designed to comply with location- and action- specific ARARs. An underground injection permit would be obtained and health and safety measures would be performed to meet the federal and Commonwealth requirements during the pilot study and the remedial action. Tables 2-2 and 2-3 summarize the location- and action-specific ARARs and their FS considerations.

Long-term Effectiveness and Permanence
Magnitude of Residual Risk – This alternative would have long-term effectiveness and permanence since contamination would be destroyed through treatment. The PRB, if necessary, and injections in the treatment zone in the saprolite would limit downgradient migration of the contaminants and accelerate the cleanup of the affected area. Currently there are no risks to human health as the

contaminated groundwater is not being used as potable water. Potential future human health risks would be reduced through the implementation of institutional controls. It is preferred to implement this alternative after the soil remedy has been completed such that any discharges from the vadose zone during soil remedy implementation would be treated by the in situ treatment under this alternative. Any future discharges from the vadose zone would not be treated once the in situ treatment has been completed. However, the contamination would eventually be captured by the PRB, if installed.

Adequacy of Controls – This alternative would provide adequate control of contamination. In situ treatment would be effective in reducing contaminant mass. However, the PRB would require reactivation periodically in order to maintain its effectiveness and would need to be maintained for a long period time until the plume concentrations have dropped to below the PRGs. Institutional controls would be enforced so that no new drinking water wells are drilled in the affected area. The effectiveness would be confirmed through long-term groundwater monitoring.

Reliability of Controls – In situ treatment is an innovative technology that would require treatability and pilot studies. However, depending on the studies, the reduction in contaminant concentration through in situ treatment and the implementation of institutional controls, if properly enforced, would be considered reasonably adequate and reliable for protection of human health. Periodic reactivation of the PRB could be problematic in the long-term. The long-term effectiveness of this alternative would be assessed through routine groundwater and surface water monitoring and five-year reviews. As part of the monitoring program, groundwater would be sampled to monitor groundwater quality over time to verify that contaminant concentrations would not be increasing over time or posing an unacceptable risk to human health and the environment.

Reduction of T/M/V through Treatment

The T/M/V of contamination at the site would be reduced through in situ treatment and also through reactions in the PRB. Concentration of contaminants present outside the treatment area would decrease slowly through dilution and dispersion.

Short-term Effectiveness

Limited site work and installation of the injection point system would be performed with significant impact to the community and workers. Site workers would follow approved health and safety plans and would wear appropriate PPE to minimize exposure to contamination and also protection from physical hazards. No adverse impacts to habitats or vegetation would be anticipated from activities associated with implementation of this alternative.

Implementability

This alternative would be implemented using experienced specialty vendors. These vendors are readily available for the required services. All required permits would be obtained. Access would be needed for both in situ treatment and the PRB installation. Access and space limitation could prevent the implementation of this alternative.

Cost

The total present worth for Alternative GW4 is $7,375,000. The estimated capital cost is $4,828,000. The estimated monitoring cost over 30 years is $2,547,000. Detailed cost estimates are presented in Appendix A.

4.4 Comparative Analysis of Remedial Alternatives

4.4.1 Comparative Analysis of IDC Soil Remedial Alternatives

4.4.1.1 Overall Protection of Human Health and the Environment

Alternative IDC-S1, No Action, would not meet the RAOs and would not be protective of the environment since no action would be taken. The site-specific HHRA indicates that the direct contact risks are within EPA's acceptable risk range for soils at IDC. Contamination would remain in the soil, while no mechanisms would be implemented to prevent migration of contaminants to the underlying groundwater, or to reduce the T/M/V of contamination except through natural attenuation processes, which would not be monitored to assess the effectiveness or predict the duration of this alternative.

Alternative IDC-S2, Containment, would meet the RAOs and would be protective of the environment if the cap is properly maintained. Since the cap would minimize the infiltration of rainwater, it would reduce the potential for the contaminants to migrate to the underlying groundwater. However, this alternative would not provide treatment to reduce the T/M/V of the contaminants except through natural attenuation processes.

Alternative IDC-S3 would provide treatment to reduce the T/M/V of the contaminants. However, a significant portion of the contaminants mass would remain because SVE could not effectively remove the contaminants from the clayey soil matrix.

The soil vapor monitoring program under Alternatives IDC-S2 and IDC-S3 would monitor for vapor intrusion to ensure human health is protected.

4.4.1.2 Compliance with ARARs

There are no Federal or Puerto Rico chemical-specific ARARs for soil. All the alternatives except No Action would comply with location-specific and action-specific ARARs. Location- and action-specific ARARs do not apply to the No action since no work would be implemented.

4.4.1.3 Long-term Effectiveness and Permanence

Under the No Action alternative, contamination would continue to be present in the vadose zone and migrate in the soil, and potentially impact groundwater at some point in the future. The No Action alternative is not effective or permanent over the long-term.

For the capping alternative, IDC-S2, the cap is not considered a permanent remedy because it does not reduce the T/M/V of contamination. A cap does have the potential to effectively meet RAOs over the long-term if the cap is well-maintained indefinitely. For Alternative IDC-S3 with SVE, technical limitations mean that most likely not all the contamination would be removed from the clayey soil. The radius of influence of SVE wells would be low in clayey soil, and environmental fracturing may not be advisable in the surface interval due to risks of damaging buildings. Significant diffusion of contamination into the clay is likely to have occurred. The SVE system may not be effective at promoting back-diffusion and extraction to the aboveground treatment system. In the remainder of the target treatment zone where SVE is not implemented, a well-maintained cap and institutional controls would be critical to the ability to meet RAOs over the long-term. Alternatives IDC-S2 and IDC-S3 also would provide vapor intrusion mitigation as necessary.

4.4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action alternative would not reduce contaminant T/M/V since no remedial action would be conducted.

The capping alternative would not reduce toxicity or volume, but would be designed to reduce mobility by minimizing infiltration of rainwater into the contaminated soil. If it is effective in the clayey soil matrix, SVE would reduce T/M/V through treatment. The extent and effectiveness of T/M/V reduction would need to be verified with monitoring.

4.4.1.5 Short-term Effectiveness

With respect to the No Action alternative, there would be no short-term impact to the community and environment as no remedial action would occur. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction and operation. Air monitoring, engineering controls, and appropriate worker PPE would be used to protect the community and workers for these alternatives.

4.4.1.6 Implementability

The No Action alternative would be easiest both technically and administratively to implement as no additional work would be performed at the site. Experienced vendors would be readily available to implement capping and SVE. An implementability concern to highlight for capping is that it would require maintenance and inspection indefinitely; it is difficult to predict if these activities would be as regular as needed in the distant future. For SVE, the major implementability limitation would be access for drill rigs to the treatment zone. Currently, the alleyway is too narrow to fit a rig. The building and alleyway would need to be modified to gain access to the treatment area. A permit would be required to discharge vapor from the SVE system to the atmosphere.

4.4.1.7 Cost

IDC Soil Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring costs	Total Present Worth
IDC-S1	$0	$0	$0
IDC-S2	$ 159,000	$ 46,000	$ 205,000
IDC-S3	$ 1,239,000	$ 556,000	$ 1,795,000

4.4.2 Comparative Analysis of Ramallo Soil Remedial Alternatives

4.4.2.1 Overall Protection of Human Health and the Environment

Alternative R-S1, No Action, would not meet the RAOs and would not be protective of the human health and the environment since no action would be taken. Contamination would remain in the soil, while no mechanisms would be implemented to prevent direct contact of the contaminated soils, migration of contaminants to the groundwater, or to reduce the T/M/V of contamination except through natural attenuation processes, which would not be monitored to assess the effectiveness or predict the duration of this alternative.

The protectiveness of Alternative R-S2, Containment, relies on continuing maintenance of a cap indefinitely. A well-maintained cap would be a barrier for direct contact and rainwater infiltration. While the cap can be expected to slow the flux of contamination from soil and into the underlying groundwater, it may not stop the flux completely; consequently, the underlying groundwater may continue to be impacted. Only monitoring over time could answer this question.

Alternative R-S3 is the most likely to be protective over time because this alternative would actively remove contaminant mass from the subsurface. SVE and thermal treatment would be expected to remove most of the contaminant mass from the treatment zone (over 90%).

Alternative RS-4 would provide treatment to the hot spot, but the effectiveness is uncertain without a pilot study. Nonetheless, given the technical limitations of these in situ treatment technologies in clayey soil, a significant portion of the contamination would not be removed and it would be necessary to rely on a cap over the long-term to ensure protectiveness. As mentioned above, reliance on long-term maintenance means capping can only be conditionally protective.

The long-term soil vapor monitoring program in Alternatives R-S2 through R-S4 would monitor for vapor intrusion to ensure human health is protected.

Alternatives R-S2, R-S3, and R-S4 would achieve the RAOs.

4.4.2.2 Compliance with ARARs

There are no Federal or Puerto Rico chemical-specific ARARs for soil. All the alternatives except No Action would comply with location-specific and action-specific ARARs. Location- and action-specific ARARs do not apply to the No Action since no work would be implemented.

4.4.2.3 Long-term Effectiveness and Permanence

Under the No Action alternative, contamination would continue to flux from the soil into groundwater and be present at unpaved ground surface where it could impact biota and humans. No Action would not be effective or permanent over the long-term.

For the capping alternative, R-S2, the cap is not considered a permanent remedy because it does not reduce the T/M/V of contamination. A cap does have the potential to effectively meet RAOs over the long-term if the cap is well-maintained indefinitely. The active remedial alternatives, R-S3 and R-S4, are the most likely to be permanent and effective over the long-term because they remove or destroy contamination in the subsurface, thus decreasing T/M/V. Thermal remediation is expected to heat the entire volume of the treatment zone, and thus would be the most effective alternative for removing diffused mass. Amendments introduced with environmental fracturing under RS-4 would diffuse into the clay to attack the existing diffused contaminants; however, introduction via discrete fractures cannot be expected to uniformly distribute amendment throughout the treatment zone, and there would likely be some gaps in treatment. As a result, not all of the contaminant mass would be removed from the clayey soil. Alternatives R-S2 through R-S4 would provide vapor intrusion mitigation as necessary. A well-maintained cap and institutional controls for Alternatives R-S2, R-S3, and R-S4 would be critical to the ability to meet RAOs over the long-term.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action alternative would not reduce contaminant T/M/V since no remedial action would be conducted.

The capping alternative would not reduce toxicity or volume, but would be designed to reduce mobility by minimizing infiltration of rainwater into the contaminated soil. The active remedies, R-S3 and R-S4, would reduce T/M/V through treatment. SVE would remove the contamination from the subsurface, and chemical treatment would destroy the contamination in situ. The extent and effectiveness of T/M/V reduction would need to be verified with monitoring for both R-S3 and R-S4.

4.4.2.5 Short-term Effectiveness

With respect to the No Action alternative, there would be no short-term impact to the community and environment as no remedial action would occur. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction, operation, and/or injection activities. Alternative R-S3 would have the highest impact since operations would last the longest, followed by R-S4, then R-S2. Air monitoring, engineering controls, and appropriate worker PPE would be used to protect the community and workers for Alternatives R-S2 through R-S4.

4.4.2.6 Implementability

The No Action alternative would be the easiest both technically and administratively to implement as no additional work would be performed at the site. Alternatives R-S2, R-S3, and R-S4 would be constructible and operable since services, materials, and experienced vendors would be readily available. Maintenance and inspection would be needed indefinitely for the capping alternative; it is difficult to predict if these activities would be performed as regularly as needed in the distant future. The in situ treatment alternative would require environmental fracturing and SVE would require thermal remediation. These are specialty environmental services and are not widely available. Lastly, R-S3 contains an excavation and disposal component. Since no landfills in Puerto Rico accept hazardous waste, difficulty could arise in the transport of excavated hazardous waste to a permitted landfill, likely somewhere in the US. A permit would also be required to emplace amendment into the subsurface and/or to discharge vapor from an SVE and thermal treatment system to the atmosphere.

4.4.2.7 Cost

Ramallo Soil Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring costs	Total Present Worth
R-S1	$0	$0	$0
R-S2	$ 299,000	$ 70,000	$ 369,000
R-S3	$ 3,664,000	$ 70,000	$ 3,734,000
R-S4	$ 1,785,000	$ 70,000	$ 1,855,000

4.4.3 Comparative Analysis of Groundwater Remedial Alternatives

4.4.3.1 Overall Protection of Human Health and the Environment

Alternative GW1, No Action, would not meet the RAOs and would not be protective of human health and the environment since no action would be taken. No mechanisms would be implemented to reduce the T/M/V of the contamination except through natural processes which would not be monitored to assess the effectiveness or predict the duration of this alternative.

Alternatives GW2, GW3, and GW4 would be effective when combined with institutional controls to prevent future human exposure to groundwater contamination. These alternatives also provide protection over time because they employ active remediation by either reducing the toxicity, mobility, or volume of contamination. These alternatives would achieve the RAO.

4.4.3.2 Compliance with ARARs

All the alternatives except No Action are anticipated to satisfy the chemical-specific ARARs by achieving the PRGs in the future and would comply with location-specific and action-specific ARARs.

4.4.3.3 Long-term Effectiveness and Permanence

Alternative GW-1, No Action, would not have long-term effectiveness since no action would be implemented to reduce the level of contamination or the potential for exposure to contaminated groundwater to site receptors.

Alternatives GW2, GW3, and GW4 would be effective since they combine treatment, long-term monitoring and institutional controls. Alternatives GW2 and GW3 would provide additional protection as the contaminants would be removed and treated ex situ while GW4 would employ in situ treatment to destroy the contaminants. The effectiveness of these alternatives would be assessed through routine groundwater monitoring and five-year reviews. Alternatives GW2 and GW3 would be equally effective, followed by Alternative GW4.

4.4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action alternative would not reduce contaminant T/M/V since no remedial action would be conducted.

Alternatives GW2, GW3, and GW4 would reduce T/M/V through treatment. GW2 and GW3 would remove contaminated groundwater and treat it ex situ while GW4 would chemically treat and destroy contamination in situ. The extent and effectiveness of T/M/V reduction would need to be verified with monitoring results. It is expected Alternatives GW2 and GW3 would have higher T/M/V reduction than Alternative GW4.

4.4.3.5 Short-term Effectiveness

With respect to the No Action alternative, there would be no short-term impact to the community, environment, and the workers as no remedial action would occur. There would be short-term impacts to the local community and workers for the remaining alternatives due to the active remedial actions undertaken and associated construction, operation, extraction and/or injection activities. Air monitoring, engineering controls, and appropriate worker PPE would be used to protect the community and workers for Alternatives GW2, GW3, and GW4. Alternative GW4 would have the highest degree of impact, followed by Alternatives GW 2 and GW3.

4.4.3.6 Implementability

The No Action alternative would be easiest both technically and administratively to implement as no additional work would be performed at the site.

Alternatives GW2, GW3, and GW4 would be constructible and operable since services, materials, and experienced vendors would be readily available. Land use and discharge permits can be easily obtained. Alternatives GW2 and GW3 would require space for the treatment plant and the interconnecting piping between the extraction wells, the treatment plant and the discharge point. Alternative GW4 would require access to a large area for injection treatment. Access and space limitations could prevent the implementation of Alternative GW4.

4.4.3.7 Cost

Groundwater Alternative	Estimated Capital Costs	Present Worth of O&M and Monitoring costs	Total Present Worth
GW1	$0	$0	$0
GW2	$ 3,032,000	$ 6,389,000	$ 9,421,000
GW3	$ 2,715,000	$ 6,166,000	$ 8,881,000
GW4	$ 4,828,000	$ 2,547,000	$ 7,375,000

Section 5

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Table 1-1
Human Health Risk Assessment Summary
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Land Use	Exposure Area	Receptor	Cancer Risk		Noncancer Hazard Index	
			RME	CTE	RME	CTE
Current	Exposure Area 2	Worker	1×10^{-6}	--	0.3	--
		Trespasser	3×10^{-8}	--	0.6	--
		Resident	6×10^{-6}	--	1	--
	Exposure Area 3	Worker	2×10^{-5}	--	3	1
	Exposure Area 4	Worker	1×10^{-5}	--	3	1
	Rio Arroyata	Recreational User	1×10^{-6}	--	2	0.6
Future	Exposure Area 1	Worker	2×10^{-4}	5×10^{-5}	8	5
		Trespasser	9×10^{-7}	--	1	--
		Resident	1×10^{-3}	2×10^{-4}	80	33
		Construction Worker	4×10^{-7}	--	4	--
	Exposure Area 2	Worker	2×10^{-4}	5×10^{-5}	8	6
		Trespasser	6×10^{-7}	--	2	0.8
		Resident	1×10^{-3}	2×10^{-4}	85	35
		Construction Worker	6×10^{-7}	--	5	--
	Exposure Area 3	Worker	2×10^{-4}	5×10^{-5}	10	6
		Trespasser	2×10^{-6}	--	2	0.5
		Resident	1×10^{-3}	3×10^{-4}	93	43
		Construction Worker	6×10^{-7}	--	4	--
	Exposure Area 4	Worker	2×10^{-4}	5×10^{-5}	8	6
		Trespasser	1×10^{-6}	--	2	0.4
		Resident	1×10^{-3}	3×10^{-4}	87	39
		Construction Worker	4×10^{-7}	--	4	--
	Rio Arroyata	Recreational User	1×10^{-6}	--	2	0.6

Exposure Area 1: Ramoncito, Don Quijote Pizza, Coffee Shop, and ESSO Gas Station/LM Auto Parts (ESSO)

Exposure Area 2: International Dry Cleaners (IDC)

Exposure Area 3: CCL Label, Ramallo/ Cidra Convention Center (CCC), and ENCO

Exposure Area 4: Shellfoam, DJ Manufacturing, IVAX, and Pepsi

Table 2-1
Chemical-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARAR	Status	Requirement Synopsis	Feasibility Study Consideration
Federal	EPA Regional Screening Level (RSL) (November 2012)	To Be Considered	Establishes risk-based screening levels for the protection of human health.	The RSL will be considered in the development of the PRGs if there are no applicable standards.
Federal	National Primary Drinking Water Standards (40 CFR 141)- MCLs	Relevant and Appropriate	Establishes health-based standards for public drinking water systems. Also establishes drinking water quality goals set at levels at which no adverse health effects are anticipated, with an adequate margin of safety. Groundwater at the site is currently not used as a source of drinking water.	The standards were used to develop the PRGs to accommodate any future use of site groundwater as a source of drinking water supply.
Federal	OSWER Vapor Intrusion Assessment: Vapor Intrusion Screening Level (VISL) Calculator Version 3.0, November 2012 RSLs	Relevant and Appropriate	Provides generally recommended screening level concentrations for groundwater, soil gas (exterior to buildings and sub-slab), and indoor air for default target risk levels and exposure scenarios	The standards were used to develop screening criteria for vapor intrusion.
Commonwealth of Puerto Rico	Puerto Rico Water Quality Standards (PRWQS) Regulation, March 2010	See remarks under "Feasibility Study Consideration".	This regulation is to preserve, maintain and enhance the quality of the waters of Puerto Rico and regulate any discharge of any pollutant to the waters of Puerto Rico by establishing water quality standards. Water quality standards and use classifications are promulgated for the protection of the uses assigned to coastal, surface, estuarine, wetlands, and ground waters of Puerto Rico.	The PRWQS are neither applicable nor relevant or appropriate chemical-specific ARARs. These standards will be evaluated under action-specific ARARs if any remedial alternatives under consideration entail any discharges to waters of Puerto Rico.

Acronyms:

ARARs - Applicable or Relevant and Appropriate Requirements

CFR - Code of Federal Regulations

PRGs - Preliminary Remediation Goals

OSWER - Office of Solid Waste and Emergency Response

MCLs - Maximum Contaminant Levels

Table 2-2
Location-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARARs	Status	Requirement Synopsis	Feasibility Study Consideration
Federal	National Historic Preservation Act (40 CFR 6.301)	Applicable	This requirement establishes procedures to provide for preservation of historical and archeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.	The effects on historical and archeological data will be evaluated during the identification, screening, and evaluation of alternatives.

Table 2-3
Action-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARARs	Status	Requirement Synopsis	Feasibility Study Consideration
General - Site Remediation				
Federal	OSHA Recording and Reporting Occupational Injuries and Illnesses (29 CFR 1904)	Applicable	This regulation outlines the record keeping and reporting requirements for an employer under OSHA.	These regulations apply to the companies contracted to implement the remedy. All applicable requirements will be met.
Federal	OSHA Occupational Safety and Health Standards (29 CFR 1910)	Applicable	These regulations specify an 8-hour time-weighted average concentration for worker exposure to various organic compounds. Training requirements for workers at hazardous waste operations are specified in 29 CFR 1910.120.	Proper respiratory equipment will be worn if it is not possible to maintain the work atmosphere below the 8-hour time-weighted average at these specified concentrations.
Federal	OSHA Safety and Health Regulations for Construction (29 CFR 1926)	Applicable	This regulation specifies the type of safety equipment and procedures to be followed during site remediation.	All appropriate safety equipment will be on-site, and appropriate procedures will be followed during remediation activities.
Federal	RCRA Identification and Listing of Hazardous Wastes (40 CFR 261)	Applicable	This regulation describes methods for identifying hazardous wastes and lists known hazardous wastes.	This regulation is applicable to the identification of hazardous wastes that are generated, treated, stored, or disposed during remedial activities.
Federal	RCRA Standards Applicable to Generators of Hazardous Wastes (40 CFR 262)	Applicable	Describes standards applicable to generators of hazardous wastes.	Standards will be followed if any hazardous wastes are generated on-site.
Federal	RCRA Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities – General Facility Standards (40 CFR 264.10–264.19)	Relevant and Appropriate	This regulation lists general facility requirements including general waste analysis, security measures, inspections, and training requirements.	Facility will be designed, constructed, and operated in accordance with this requirement. All workers will be properly trained.
Commonwealth of Puerto Rico	Regulation of the Puerto Rico Environmental Quality Board (PREQB) for the Prevention and Control of Noise Pollution	Applicable	This standard provides the standards and requirements for noise control.	This standard will be applied to any remediation activities performed at the site.
Commonwealth of Puerto Rico	Puerto Rico's Anti-degradation Policy	Applicable	Conserve, maintain and protect the designated and existing uses of the waters of Puerto Rico. The water quality necessary to protect existing uses, including threatened and endangered species shall be maintained and protected.	The requirement will be considered during the development of alternatives. The potential effects of any action will be evaluated to ensure that any endangered or threatened species and their habitat will not be affected.

Table 2-3
Action-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARARs	Status	Requirement Synopsis	Feasibility Study Consideration
Waste Transportation				
Federal	Department of Transportation (DOT) Rules for Transportation of Hazardous Materials (49 CFR Parts 107, 171, 172, 177 to 179)	Applicable	This regulation outlines procedures for the packaging, labeling, manifesting, and transporting hazardous materials.	Any company contracted to transport hazardous material from the site will be required to comply with this regulation.
Federal	RCRA Standards Applicable to Transporters of Hazardous Waste (40 CFR 263)	Applicable	Establishes standards for hazardous waste transporters.	Any company contracted to transport hazardous material from the site will be required to comply with this regulation.
Waste Disposal				
Federal	RCRA Land Disposal Restrictions (40 CFR 268)	Applicable	This regulation identifies hazardous wastes restricted for land disposal and provides treatment standards for land disposal.	Hazardous wastes will be treated to meet disposal requirements.
Federal	RCRA Hazardous Waste Permit Program (40 CFR 270)	Applicable	This regulation establishes provisions covering basic EPA permitting requirements.	All permitting requirements of EPA must be complied with.
Commonwealth of Puerto Rico	PREQB Regulation for the Control of Non-Hazardous Solid Waste (November 1997)	Applicable	This regulation establishes standards for the generation, management, transportation, recovery, disposal and management of non-hazardous solid waste.	Control activities for the non-hazardous wastes must comply with the treatment and disposal standards.
Commonwealth of Puerto Rico	PREQB Regulation for the Control of Hazardous Solid Waste (September 1998)	Relevant and Appropriate	This regulation establishes standards for management and disposal of hazardous wastes.	All remedial activities must adhere to these regulations while handling hazardous waste during remedial operations.

Table 2-3
Action-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARARs	Status	Requirement Synopsis	Feasibility Study Consideration
Water Discharge or Subsurface Injection				
Federal	National Pollutant Discharge Elimination System (NPDES) (40 CFR 100 et seq.)	Applicable	NPDES permit requirements for point source discharges must be met, including the NPDES Best Management Practice (BMP) Program. These regulations include, but are not limited to, requirements for compliance with water quality standards, a discharge monitoring system, and records maintenance.	Project will meet NPDES permit requirements for point source discharges.
Federal	Safe Drinking Water Act – Underground Injection Control (UIC) Program (40 CFR 144, 146)	Relevant and Appropriate	Establish performance standards, well requirements, and permitting requirements for groundwater re-injection wells.	Project will evaluate the requirement for injection of reagent for in situ treatment.
Commonwealth of Puerto Rico	Puerto Rico Water Quality Standards (PRWQS) Regulation, March 2010	Applicable	This regulation is to preserve, maintain and enhance the quality of the waters of Puerto Rico and regulate any discharge of any pollutant to the waters of Puerto Rico by establishing water quality standards. Water quality standards and use classifications are promulgated for the protection of the uses assigned to coastal, surface, estuarine, wetlands, and ground waters of Puerto Rico.	Project will meet PRWQS requirements for point source discharges.

Table 2-3
Action-specific ARARs, Criteria, and Guidance
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Regulatory Level	ARARs	Status	Requirement Synopsis	Feasibility Study Consideration
Off-Gas Management				
Federal	Clean Air Act (CAA)—National Ambient Air Quality Standards (NAAQs) (40 CFR 50)	Applicable	These provide air quality standards for particulate matter, lead, NO_2, SO_2, CO, and volatile organic matter.	During remediation and treatment, air emissions will be properly controlled and monitored to comply with these standards.
Federal	Standards of Performance for New Stationary Sources (40 CFR 60)	Relevant and Appropriate	Set the general requirements for air quality.	During remediation and treatment, air emissions will be properly controlled and monitored to comply with these standards.
Federal	National Emission Standards for Hazardous Air Pollutants (40 CFR 61)	Applicable	These provide air quality standards for hazardous air pollutants.	During remediation and treatment, air emissions will be properly controlled and monitored to comply with these standards.
Federal	Federal Directive - Control of Air Emissions from Superfund Air Strippers (OSWER Directive 9355.0-28)	Applicable	Provides guidance on control of air emissions from air strippers used at Superfund Sites for groundwater treatment.	During treatment, air emissions will be properly controlled and monitored to comply with these standards.
Commonwealth of Puerto Rico	PREQB Regulation for the Control of Atmospheric Pollution (1995)	Applicable	Describes requirements and procedures for obtaining air permits and certificates; rules that govern the emission of contaminants into the ambient atmosphere.	Need to meet requirements when discharging off-gas. Need to meet fugitive emissions requirements during remediation and treatment. Need to meet visible emissions requirements for motor vehicles.

Acronyms:

ARARs - Applicable or Relevant and Appropriate Requirements
OSHA - Occupational Safety and Health Administration
CFR - Code of Federal Regulations
RCRA - Resource Conservation and Recovery Act
EPA - Environmental Protection Agency

NO_2 - Nitrogen dioxide
SO_2 - Sulfur dioxide
CO - Carbon monoxide
OSWER - Office of Solid Waste and Emergency Response

Table 2-4a
Preliminary Remediation Goals for Soil
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Contaminants of Concern	Soil Protective of Groundwater[1]	Human Health Risk[2]	PRGs[3]	Maximum Detected Concentrations[4]
	µg/kg	µg/kg	µg/kg	µg/kg
Volatile Organic Compounds				
cis-1,2-Dichloroethylene	139	-	139	41,000
Tetrachloroethylene	24	107,000	24	3,300,000
Trichloroethylene	15	-	15	2,700
Vinyl chloride	0.3	-	0.3	2,000

Notes:

1. For protection of groundwater soil levels, based on a dilution factor of 20.
2. Direct contact risk for future residents and site workers due to inhalation of tetrachloroethylene.
3. The lowest value from levels based on protection to groundwater and human health risk.
4. The maximum concentrations detected at the Site during Stage 1, Stage 2 and Stage 2a monitoring well sampling events.

Acronyms:

µg/kg - microgram per kilogram

PRGs - Preliminary Remediation Goals

Table 2-4b
Screening Criteria for Vapor Intrusion
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Contaminants of Concern	CAS Number	Screening Level[1]	Maximum Detected Concentrations[2]
		µg/m³	µg/m³
Volatile Organic Compounds			
Residential Screening Levels			
Sub-Slab			
cis-1,2-Dichloroethylene	156-59-2	N/A	89
Tetrachloroethylene	127-18-4	94	9,400
Trichloroethylene	79-01-6	4.3	520
Vinyl chloride	75-01-4	1.6	ND
Indoor Air			
cis-1,2-Dichloroethylene	156-59-2	N/A	0
Tetrachloroethylene	127-18-4	9.4	4.8
Trichloroethylene	79-01-6	0.43	0.22
Vinyl chloride	75-01-4	0.16	ND
Commercial/Industrial Screening Levels			
Sub-Slab			
cis-1,2-Dichloroethylene	156-59-2	N/A	ND
Tetrachloroethylene	127-18-4	472	2,200,000
Trichloroethylene	79-01-6	30	4
Vinyl chloride	75-01-4	28	ND
Indoor Air			
cis-1,2-Dichloroethylene	156-59-2	N/A	0.16
Tetrachloroethylene	127-18-4	47	31
Trichloroethylene	79-01-6	3.0	0.69
Vinyl chloride	75-01-4	2.79	ND
Ambient Air			
cis-1,2-Dichloroethylene	156-59-2	N/A	ND
Tetrachloroethylene	127-18-4	9.4	ND
Trichloroethylene	79-01-6	0.43	0.62
Vinyl chloride	75-01-4	0.16	ND

Notes:

1. Screening levels are based on EPA Vapor Intrusion Screening Levels (VISLs) dated November 2012(EPA 2013). Target concentrations are based on a cancer risk of 1 in 1,000,000.

2. The maximum concentrations detected during sampling events.

Acronyms:

µg/m³ - microgram per cubic meter

EPA - United States Environmental Protection Agency

N/A - not available

Table 2-4c
Preliminary Remediation Goals for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Contaminants of Concern	National Primary Drinking Water Standards (EPA MCLs)[1] (µg/L)	PRGs[2] (µg/L)	Maximum Detected Concentrations[3] (µg/L)
Volatile Organic Compounds			
cis-1,2-Dichloroethene	70	70	74
Tetrachloroethene	5	5	1700
Trichloroethene	5	5	31
Vinyl chloride	2	2	0.17

Notes:

1. EPA National Primary Drinking Water Standards (web page), EPA 816-F-09-004, May 2009.
2. Based on the EPA MCLs.
3. The maximum concentrations detected at the Site during Stage 1, Stage 2 and Stage 2a monitoring well sampling events.

Acronyms:

EPA - United States Environmental Protection Agency
MCLs - Maximum Contaminant Levels
PRGs - Preliminary Remediation Goals
µg/L - microgram per liter

Table 2-5
Screening of Technologies and Process Options for Soil
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Technology Type	Process Option	Description	Screening for Effectiveness, Implementability, and Relative Cost			Retained?
				Effectiveness	Implementability	Relative Cost	
No Action	No Action	No Action	No action is performed at the site.	Not effective, but required for consideration by the NCP as a baseline for comparison. Unlikely to be acceptable due to the level of contaminants on site. Not protective of the environment.	Easily implemented	None	Retained (required by NCP as stand-alone alternative)
Institutional Controls	Land Use Controls	Governmental and Proprietary Controls	Contact with contaminated medium would be controlled through zoning and restrictions governing land use of the site.	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Implemented using legal instruments and labor resources; potential public resistance; zoning requires the cooperation of the municipality.	Low	Retained
		Informational Devices	Contact with contaminated medium would be controlled through legal instruments such as Notices of Environmental Contamination or deed notices	Restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination.	Somewhat easily implemented using legal instruments and labor resources; potential public resistance.	Low	Retained
	Community Awareness	Information and Education Programs	Community information and education programs would be undertaken to enhance awareness of potential hazards and remedies.	Protects human receptors by enhancing awareness of potential site hazards and remedies. Does not directly affect ecological receptors and does not physically address contaminants.	Easily implemented using available technical and community involvement labor resources.	Low	Retained
	Monitoring	Sampling of environmental media.	Periodic monitoring of environmental media would be conducted. Can be both short-term and long-term.	Protects human receptors by monitoring contaminant concentrations and migration. Does not directly affect receptors and does not physically address contaminants.	Easily implemented using available technical labor and equipment resources.	Low to Moderate	Retained
Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Reliance on natural destructive and nondestructive mechanisms to reduce contaminant levels in the context of a long term monitoring program.	Effective where natural mechanisms have been shown to be able to meet the RAOs within a reasonable timeframe.	Easily implemented using available technical labor and equipment resources.	Low to Moderate	Eliminated from consideration due to effectiveness issues (not anticipated to meet RAOs within a reasonable timeframe).
Containment	Capping	Asphalt, concrete, or Clay Cap	Cover surface with low-permeability material such as asphalt, concrete or clay to prevent exposure to contaminated materials and limit water infiltration.	Protects human receptors by eliminating surface exposure of contaminants and minimizes water infiltration into subsurface, with the use of a relatively thin cap construction. Does not physically address existing contamination. Does not lessen toxicity or volume of contamination in subsurface soil. Limitations include the following: potential for saturated contaminated subsurface soil under cap to release contamination to groundwater, potential of mobile NAPL to continue downward migration to the water table. Effectiveness of clay caps may decrease over time due to development of desiccation cracking.	Implemented using available construction resources and materials. Requires increased maintenance for long-term protectiveness. Buildings on treatment zone footprint may need to be demolished.	Moderate	Retained
Removal	Excavation	Mechanical Excavation & Backfill	Excavation of contaminated soil to the extent possible using typical construction equipment.	Protects human receptors by eliminating surface exposure of contaminants and reducing subsurface contaminants. Effective technique for removing contaminated soil from the site. Must be combined with transport, disposal, and/or treatment technologies. Engineering controls may be necessary to capture emissions of contaminants volatized during removal of contaminated soils.	Difficult to implement due to depth of excavation and proximity of neighboring buildings. Sheet piles would be required for the deep excavation and to prevent structural disturbance of neighboring buildings which would not allow excavation of the full extent of contamination. Must be combined with engineering controls during implementation to provide protection to workers and the environment. As part of the excavation the on-site buildings would need to be demolished or modified.	Moderate	Retained in combination with other technologies.

Table 2-5
Screening of Technologies and Process Options for Soil
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Technology Type	Process Option	Description	Screening for Effectiveness, Implementability, and Relative Cost			Retained?
				Effectiveness	Implementability	Relative Cost	
Treatment	Thermal	In situ Electrical Resistance Heating	Uses arrays of electrodes to apply electrical current to the subsurface. Heat generated by electrical resistance in the soil accelerates volatilization of the contaminants.	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Very effective in mobilizing residual DNAPL for collection and treatment. Requires vapor extraction and treatment.	Relatively easy to implement using readily available equipment if size of treatment zone is limited. Can be applied under roads and existing buildings if space is available for drill rigs during installation. The technology requires a significant, reliable source of electrical power in order to provide capacity to heat soil. Presence of low permeability silt and clay layer above the aquifer may necessitate creation of a permeable zone in order for SVE to be implemented. Buildings on treatment zone footprint may need to be demolished or modified.	High	Retained
		In situ Thermal Conductive Heating	Electricity or natural gas is used to raise the temperature of heater wells. The heat is transferred to the surrounding formation via thermal conduction. The heater wells and adjacent soil can reach temperatures in excess of 500 degrees Celsius. As the soil is heated, contaminants are vaporized or destroyed and drawn by vacuum into the wells in a direction countercurrent to the heat flow.	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Thermal wells have been demonstrated to be highly effective in removing chlorinated solvents from soils.	The technology requires a significant, reliable source of electrical power or natural gas. Vertical wells would need to be installed in triangular grids at a spacing of 5 to 7 feet between wells. Buildings on treatment zone footprint may need to be demolished or modified.	High	Retained
		Ex situ Incineration	High temperature (2000 °F) burning of soil that destroys organic materials. Can be conducted either on site in a mobile unit or off site.	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Treated soil would be backfilled or disposed following incineration.	Difficult to implement due to limited availability of equipment and operators. Anticipate difficulty obtaining local acceptance to site an incinerator for onsite treatment.	Very High	Eliminated from consideration due to cost and implementability issues (availability of equipment and personnel).
		Ex Situ Low Temperature Thermal Desorption	Low temperature (300-600 °F) process that volatilizes organic materials, which are captured and processed in an off-gas treatment system or recycled.	Protects receptors by eliminating exposure to contaminants and reducing concentrations of contaminants. Clay and silty soils and high humic content soils increase reaction times as a result of binding of contaminants. Particle size can reduce performance of technology so soil may need to be pre-screened and re-worked.	Equipment and labor resources somewhat readily available. Requires specialized technical personnel for installation of equipment. Off-gas treatment may be required for dust and vapor emissions. May encounter difficulties meeting air discharge requirements. High energy requirements due to high contaminant concentrations. Process has intensive startup and monitoring requirements.	High	Eliminated
	Biological	Enhanced In situ Bioremediation	Uses injection of amendments to stimulate biotic degradation of contaminants	Reduce concentrations of contaminants. Most effective on dissolved-phase organics. Recent studies show that it can be effective in source areas with residual DNAPL as well.	Relatively easy to implement using readily available equipment. Also there is a large suite of suitable bioremediation amendments that can be selected during design. Amendment delivery can be challenging in clayey formations. Limitations to implementability include the following: delivery method for nutrients, presence of nutrients in subsurface, and type of microorganisms present in subsurface. Requires relatively long timeframe for remediation (years to decades) if high concentrations of VOCs or DNAPL are present.	Moderate	Retained.

Table 2-5
Screening of Technologies and Process Options for Soil
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Technology Type	Process Option	Description	Screening for Effectiveness, Implementability, and Relative Cost			Retained?
				Effectiveness	Implementability	Relative Cost	
	Physical	Soil Vapor Extraction	Establishes a vacuum in either the vadose zone (ex situ) or a mound of excavated soil (ex situ) to volatilize and extract organic contaminants from soil.	Protects receptors by reducing concentration of contaminants in soil. Effective for removing organic contaminants from soil. Limited effectiveness in site geology consisting of damp, low permeability silt and clay (moisture content is approximately 30%) which would limit the radius of influence of the extraction wells and may cause short circuiting.	Relatively easy to implement using readily available equipment. System may require off-gas treatment to address air emissions. Residual liquids and spent treatment materials may require further treatment. Presence of low permeability silt and clay layer above the aquifer may necessitate enhancements, such as creation of a permeable gravel-filled trench or pneumatic fracturing to increase secondary porosity. Buildings on treatment zone footprint may need to be modified, or the surface soils may require excavation.	Low	Retained
Treatment (continued)	Chemical	In-situ Chemical Oxidation	An oxidizing agent (e.g., hydrogen peroxide, Fenton's Reagent, potassium permanganate, persulfate, or ozone) is mixed into the subsurface. Dissolved organic compounds are destroyed upon reaction with the oxidant.	Protects receptors by reducing concentration of contaminants in subsurface. Effective organic destruction if adequate contact between reagents and dissolved contaminants occurs in a saturated soil.	Achieving good distribution of the oxidant throughout the unsaturated, low-permeability clay of the treatment zone would be difficult. Injection would have a very limited range of influence in this geology and not be cost effective. Even with the use of environmental fracturing technologies, the oxidants would be in primary or secondary fractures that would still require the oxidant to diffuse up and out of the clay matrix. In situ soil mixing is a technique that could mechanically mix the amendment and water into the clay and create the contact and saturation needed for successful remediation. Space limitations at the Site for soil mixing equipment may affect implementability. Buildings on treatment zone footprint may need to be demolished or modified.	Moderate to High	Retained.
		In situ Chemical Reduction	The technology involves the injection of reductants such as nano-or micro-scale zero valent iron (ZVI) particles to reduce the contaminants to non-hazardous compounds.	Protects receptors by reducing concentration of contaminants in subsurface. Effective VOCs destruction if adequate contact between reagents and dissolved contaminants occurs. Achieving uniform delivery of the reductant and adequate contact of reductant with contaminants would be critical for effective treatment.	Since ZVI is a particle and is larger than the pore space in clayey soils, fracturing would be required in the clayey soils of the vadose zone, and the ZVI would be emplaced along the fractures.	High capital cost, depending on the delivery technology and the depth required to be achieved.	Retained.
Disposal	Off-site Disposal	Non-Hazardous Waste Landfill	Disposing excavated soil in an off-site non-hazardous waste landfill.	Disposal in non-hazardous waste landfill is effective in preventing direct contact and in reducing mobility of contaminants; however the volume and toxicity of the waste is not reduced.	This technology is technically implementable. However, offsite disposal at a non-hazardous waste landfill would need to be implemented with a removal action. Since excavation is retained, offsite disposal at a non-hazardous landfill would be implemented.	Moderate	Retained.
		Hazardous Waste Landfill	Disposing excavated soil in an off-site, permitted, RCRA hazardous waste landfill.	Effective for disposal of materials that do not meet required treatment under the RCRA LDRs. Effective in preventing direct contact and in reducing mobility of contaminants; however the volume and toxicity of the waste are not reduced.	RCRA Subtitle C landfills that accept contaminated soils are available. However, this process option needs to be implemented with the removal action for contaminated soil. .	High	Retained.

Acronyms:
ARAR: applicable or relevant and appropriate requirement
DNAPL: dense non-aqueous phase liquid
GAC: granular activated carbon
NCP: National Oil and Hazardous Substances Pollution Contingency Plan
O&M: operations and maintenance
PCE: tetrachloroethene
SVE: soil vapor extraction
VOC: volatile organic compounds

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
No Action	None	None	The No Action alternative is retained as a baseline for comparison with other alternatives as required by National Contingency Plan (NCP). No remedial actions would be implemented. The Site-wide groundwater contamination would remain in its existing condition.	The No Action Response is not effective. It does not prevent human exposure to contaminated groundwater. It does not protect the environment. It does not meet the remedial action objectives (RAOs).	Implementable. Minor administrative action may be needed.	No capital, operation or maintenance costs.	Yes	Yes
Institutional/Engineering Controls	Institutional Controls	Land Use Controls	Land use controls are used to prevent certain types of uses for properties where exposure pathways to contaminants may be created as a result of those uses. They may be used to require the installation of a vapor mitigation system; or prevent well drilling activities within the contamination plume. They are generally administrated by local government.	Effective in reducing risks to human health by restricting or eliminating use of contaminated groundwater. The effectiveness depends on proper enforcement. Would not reduce the migration and environmental impact of the contaminated groundwater in any of the contaminant plumes.	May not be easy to implement. Utilizes the existing permitting process. Their implementability highly depends on the local government and its enforcement system.	Implementation cost is low. Some administrative, long-term monitoring and periodic assessment costs would be required.	Yes	Yes
	Community Awareness	Information and Education Programs	Community information and education programs would be undertaken to enhance awareness of potential hazards, available technologies capable to address the contamination, and remediation progress to the local community.	Educational programs would protect human health by creating awareness and would enhance the implementation of deed restrictions within the contaminated aquifer.	Implementable.	Low capital cost and operational costs.	Yes	Yes
	Monitoring	Monitoring	Periodic environmental monitoring to determine extent of contaminant plume.	Not effective in reducing contamination levels by itself. Would not alter the risk to human health or the effect on the environment. Effective in providing information on Site conditions.	Easily implementable.	Medium capital cost if monitoring well network needs to be established. Medium operation and maintenance (O&M) costs.	Yes	Yes

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Monitored Natural Attenuation (MNA)	MNA	MNA	Relies on natural destructive (biodegradation and abiotic degradation) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption) to reduce contaminant levels within a reasonable time frame. Implemented with a long-term monitoring program. Under favorable conditions, these physical, chemical, or biological processes act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater.	Effective for sites where multiple years of data have demonstrated that the contaminant plume is contained or shrinking; destructive attenuation mechanisms are active and responsible for containing the plume; and sufficient evidence exists that these mechanisms would persist for the required time of plume management. While some degree of reductive dechlorination has or is occurring—as demonstrated by the detection of TCE and cis-1,2-DCE—the lack of detected vinyl chloride and the low total organic carbon (<2 mg/L) in the plume indicate that either DHC may not be present, or there may be insufficient organic carbon to sustain the dechlorinating microbes.	Materials and services necessary to model and monitor the contaminant dynamics are readily available. Institutional/engineering controls would be required to minimize human exposure to contaminants.	Low capital costs and medium O&M costs	Not retained; not anticipated to meet RAOs within a reasonable timeframe	Not retained; not anticipated to meet RAOs within a reasonable timeframe
Containment	Vertical Barrier	Slurry Walls	Slurry walls are constructed by emplacing low-permeability slurry (typically either a soil-bentonite mixture or a cement-bentonite mixture) in an excavated trench.	Eliminates migration of contaminated groundwater horizontally and reduces mobility of the plume. Slurry wall barriers are effective in preventing additional groundwater contamination from migrating off-Site or for diverting uncontaminated groundwater around a contaminant source. Effectiveness is limited if a confining layer is not continuous below source area.	Slurry walls are not constructible at this Site since the contaminated aquifer is at too deep a depth.	High capital cost, depending upon the depth to which the walls are installed.	No, due to lack of effectiveness and implementability	No, due to lack of effectiveness and implementability

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Containment	Vertical Barrier	Sheet Pile Barriers	Sheet pile barriers are constructed by driving or vibrating sections of steel sheet piling into the ground. Each sheet pile section is interlocked at its edges, and the seams are often grouted to prevent leakage.	If good, non-leaking, joints are installed, the sheet piling may be effective in preventing additional groundwater contamination from migrating off-Site or for diverting uncontaminated groundwater around a contaminant source. Effectiveness is limited if joints are leaking.	Not constructible at this Site since the contaminated aquifer is at too deep a depth.	High capital cost, depending upon the depth to which the walls are installed.	No, due to lack of effectiveness and implementability	No, due to lack of effectiveness and implementability
Extraction	Groundwater Extraction	Extraction Wells	Installation of groundwater extraction wells to provide hydraulic control and capture of contaminant migration. Effective when combined with other treatment and discharge technologies.	Effective in providing hydraulic control and removal at sites where the soil is highly permeable, hydrogeology is well understood and the pumping rate necessary to maintain hydraulic control is sustainable. Reduces migration of contaminated groundwater and reduces concentrations of contaminants in groundwater over time. Must be combined with treatment and disposal. Can be effective in the porous saprolite. Effectiveness is unknown in the bedrock.	Installation of groundwater extraction wells would be technically implementable in the saprolite. Due to the complexity of bedding planes and fractures in the bedrock, it would be difficult to predict with certainty where extraction wells should be screened in order to extract contamination.	Medium to high capital cost due to depth of drilling. Medium O&M cost due to prolonged period of operation generally required.	Yes	Yes
		Extraction Trenches	Extraction trenches are constructed perpendicular to the direction of groundwater flow to intercept and prevent downgradient migration of a contaminant plume. Extraction trenches are generally used for contamination at shallow depth.	Effective in capturing groundwater to provide hydraulic control.	Necessary equipment and materials are readily available. Not typically installed at depths greater than 30 feet bgs due to trenching equipment limitations.	High capital cost due to depth. Medium O&M cost.	No, due to lack of implementability.	No, due to lack of implementability.

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Treatment	Ex-situ Treatment	Air Stripping	Air stripping is a physical mass transfer process that uses clean air to remove dissolved volatile organic compounds (VOCs) from water by increasing the surface area of the groundwater exposed to air. In general, the water stream exiting the air stripper can be discharged to surface water or groundwater. The vapor effluent would likely require treatment (e.g., carbon adsorption or thermal or catalytic oxidation) before discharge to the atmosphere.	Effective in removing VOCs from water. The Henry's law constants for most of the Site contaminants indicate that these can be removed in the air stripper. Contaminants extracted from the contaminant plumes could be effectively treated. The process is susceptible to inorganic fouling and may require pretreatment steps such as pH adjustment or annual maintenance such as acid cleaning of the air stripper interior. Based on the low contaminant mass in the plumes, off-gas will likely not require treatment prior to discharge.	Implementable. Vendors and equipment are readily available to provide air strippers for groundwater VOC removal. Needs to be implemented with groundwater extraction and discharge technologies. May require permit for discharge of VOCs to the atmosphere and/or off-gas treatment (i.e., vapor phase carbon) prior to discharge.	Low capital and low O&M costs.	Yes	Yes
Treatment	Ex-situ Treatment	Potassium Permanganate Oxidation	Off-gas is pumped through vessel(s) containing an ion exchange resin impregnated with a solution of potassium permanganate. Oxidizing compounds, such as manganese tetraoxide, form inside the vessel and destroy VOCs passing through, include vinyl chloride.	Potassium permanganate oxidation would be effective in removing contaminants including PCE, TCE, and vinyl chloride, in the system off-gas.	Potassium permanganate oxidation systems are implementable and a proven technology. The equipment and materials would be readily available through vendors. It could be implemented with groundwater extraction or in situ thermal remediation technologies.	Low capital and medium O&M costs.	Yes	Yes
		Granular Activated Carbon (GAC) Adsorption	Extracted groundwater or off-gas is pumped through vessel(s) containing GAC to which contaminants adsorb and are removed. When the concentration of contaminants in the effluent exceeds a pre-established value (breakthrough), the GAC is removed for regeneration or disposal.	Protects human receptors by reducing concentrations in groundwater. Effective in removing contaminants with moderate or high organic carbon partition coefficients (K_{oc}) from groundwater. Not effective in removing VC, which does not effectively adsorb to carbon. Not very effective in removing cis-1,2-DCE or VC which has the tendency to break through quickly. May be susceptible to biological and inorganic fouling. Particularly effective for polishing water discharges from other technologies to attain regulatory compliance.	Implementable. The equipment and materials are readily available. Logistic and economic disadvantages arise from the need to transport and decontaminate spent carbon. Costs are high if it is used as the primary treatment on waste streams with high contaminant concentration levels. It would need to be combined with groundwater extraction and discharge technologies. O&M requirements include monitoring of influent and effluent streams, regeneration and replacement of carbon, and backwashing.	Medium capital and O&M costs.	Yes	Yes

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Treatment	Ex-situ Treatment	Ultraviolet (UV) /Oxidation	Extracted groundwater is transferred to a reactor where it is combined with ozone and/or hydrogen peroxide and irradiated with UV light. Organic contaminants are destroyed as a result of the synergistic action of the oxidant with UV light. System may require off-gas treatment to destroy unreacted ozone and volatilized contaminants. This process option is used when destruction of contaminants is preferred or when contaminants cannot be removed with GAC or air stripping.	Effective in treating chlorinated VOC contaminants including VC, in groundwater extracted from the contaminant plumes of the Site. Aqueous stream must have good transmissivity; high turbidity causes interference. This technology would not be cost effective to treat contaminants extracted from a low concentration plume such as at the Site.	Implementable. Vendors and equipment are readily available. Can be implemented with groundwater extraction and discharge technologies. Minor administrative difficulties anticipated for implementation of a UV oxidation system; may require permit for discharge of unreacted ozone and volatilized VOCs. Alternatively, treatment of off-gas may be required.	High capital and O&M costs. Generally, more costly than an equivalently sized GAC unit. Requires more electricity to operate.	Yes	Yes
	In situ Treatment	In situ Thermal Remediation	Heat is transferred to the subsurface, causing VOCs to vaporize and evaporate. Heat can be delivered by steam, conduction or by electrical resistivity heating (ERH).	In situ thermal remediation has been successfully applied to desorb and volatilize contamination sources in the geology at the Site: fractured/porous bedrock and competent bedrock	The technology would require a significant, reliable source of electrical power to heat the aquifer. Effective vapor capture would be difficult to implement at the site because the saprolite is a confined aquifer. The vadose zone (where the vapor extraction wells would be screened) is a low permeability clay, and therefore the radius of influence of the vapor extraction wells would be prohibitively small.	High capital and O&M costs over a short period, approximately one or two years.	No, due to effectiveness and implementability concerns.	No, due to effectiveness and implementability concerns.

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Treatment (continued)	In situ Treatment	Air Sparging	Air sparging involves the injection of air or oxygen into the contaminated aquifer. Injected air strips organic contaminants in situ and helps to flush the contaminants into the unsaturated zone. If the mass of VOCs is great enough, SVE may be implemented in conjunction with air sparging to remove the vapor-phase contamination from the vadose zone by vacuum extraction.	Protects human receptors by reducing concentrations of contaminants in groundwater. Effective for volatile, relatively insoluble organics. The saprolite is highly permeable but not sandy, and the permeability of the bedrock aquifer is along the bedding planes. Controlling the migration of the sparged vapors in fractured bedrock systems where the pathways may follow the orientation of fractures could be problematic. Since air sparging treats the dissolved phase, back diffusion and desorption from mass stored in the aquifer matrix could make it difficult to achieve RAOs within a reasonable timeframe	Effective vapor capture would be difficult to implement at the site because the saprolite is a confined aquifer. The vadose zone (where the vapor extraction wells would be screened) is a low permeability clay, and therefore the radius of influence of the vapor extraction wells would be prohibitively small	Moderate capital and O&M costs.	No due to effectiveness and implementability concerns.	No due to effectiveness and implementability concerns.
		In situ Chemical Reduction (ISCR)	The technology involves the injection of reductants such as nano-or micro-scale zero valent iron (ZVI) particles to reduce the contaminants to non-hazardous compounds.	ZVI can effectively treat groundwater containing PCE and its degradation byproducts. Achieving uniform delivery of the reductant and adequate contact of reductant with contaminants would be critical for effective treatment.	Achieving uniform delivery is the key implementation hurdle for in-situ chemical reduction. Injection is believed to be capable of distributing the reductant uniformly in the relatively porous saprolite. In the bedrock, injection would emplace the ZVI along existing fractures and bedding planes. To expand beyond these existing features would require hydraulic fracturing. However, fracturing could potentially connect previously unconnected bedding planes, leading to further migration of the contamination.	High capital cost, depending on the delivery technology and the depth required to be achieved.	Yes.	Yes
		In situ Chemical Oxidation (ISCO)	ISCO involves the injection of chemical oxidants (e.g., hydrogen peroxide, Fenton's reagent and/or persulfate) into the subsurface to destroy organic contaminants in groundwater. Complete oxidation of contaminants results in their breakdown into non-toxic compounds, such as carbon dioxide, water, and minerals.	Capable of reducing contaminant mass in high concentration plumes and thereby protects human receptors. Not effective for application in low concentration plumes. Effective contaminant destruction if adequate contact between reagents and contaminants occurs (i.e., adequate quantity of oxidant distributed and in contact with contaminants long enough for oxidation to occur). Another limitation on effectiveness is the limited lifespan of the oxidizing agent. Repeat application of oxidant is generally required. Can interfere with anaerobic degradation processes.	Equipment and vendors would be available for ISCO implementation, but may have to travel from the continental US. Achieving uniform delivery is the key implementation hurdle. Injection is believed to be capable of distributing the oxidant uniformly in the relatively porous saprolite. In bedrock, injection would distribute amendment primarily along existing fractures and bedding planes. To expand beyond these features (into the bedrock matrix) would require hydraulic fracturing. However, fracturing could potentially connect previously unconnected bedding planes, leading to further migration of the contamination.	High capital costs. Low O&M costs.	Yes	Yes

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Treatment (continued)	In situ Treatment	In situ Bioremediation	Involves injection of amendments to stimulate the anaerobic degradation process.	The relatively high groundwater temperature in Puerto Rico is conducive to microbial growth. The plume in the saprolite and bedrock are mostly anaerobic (dissolved oxygen less than 1 mg/L), and have low concentrations of competing electron acceptors (nitrate, sulfate). The presence of methane in the groundwater indicates that methanogenic conditions may be present in some parts of the aquifer. Introductions of a carbon source such as EVO would provide the carbon substrate necessary for microbial growth. Given the lack of detected vinyl chloride, the groundwater may need to be augmented with dechlorinating bacteria in addition to carbon substrate.	The large areal extent of contamination and the depth to groundwater would make amendment delivery costly. Amendment distribution in the saprolite will be assisted by high groundwater flow velocity. Distribution into the bedrock may require pumping.	Medium capital costs. Low O&M costs.	Yes	Yes.
Discharge	On-Site Discharge	On-Site Injection	Treated groundwater is injected into the subsurface using a series of wells. Injection requires that the groundwater be treated to meet applicable groundwater standards prior to disposal to the subsurface.	The effectiveness of this option would rely on proper injection well design and construction, including adequate pipe sizing, proper placement of the wells, and reliable construction materials. Lack of effectiveness in the bedrock due to lower permeability.	Easily implementable using available construction resources and equipment. Some implementability problems could arise during long-term operation of injection wells, such as clogging of screen packs with precipitates or microbial fouling, particularly in high iron conditions.	Medium capital costs. Medium O&M costs if well rehabilitation needs to be performed periodically.	Yes	Yes
		On-Site Surface Recharge	Groundwater is discharged through use of a surface recharge system such as an excavated recharge basin which is a shallow, man-made pond that generally requires large surface area. Extracted groundwater needs to be treated to meet standards.	On-site surface recharge would not be effective because overburden is clay and silty clay which has a very slow infiltration rate.	Readily implementable, as standard construction methods and materials would be utilized. However, space is limited and may not be enough for a recharge basin.	Low capital and O&M costs.	No, due to lack of effectiveness and implementability.	No, due to lack of effectiveness and implementability.

Table 2-6
Screening of Technologies and Process Options for Groundwater
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

General Response Action	Remedial Technology	Process Option	Description of Response Action	Effectiveness	Implementability	Relative Cost	Retained for Saprolite Aquifer	Retained for Bedrock Aquifer
Discharge		Surface Water Discharge	Treated groundwater can be discharged to a surface water body such as a nearby pond or stream. Disposal to an off-Site surface water body would require that the extracted groundwater be treated to meet applicable surface water discharge standards.	Discharge to an off-Site surface water body would be an effective method for disposal of treated groundwater, depending on the distance from the treatment system to the stream. Discharge to a surface water body such as the Rio Arroyata would be an effective method for disposal of treated groundwater.	Easily implementable using available construction resources. Would be required to meet substantive requirements of NPDES permit and PRWQS for discharge.	Low capital and O&M costs.	Yes	Yes
Discharge	Off-Site Discharge	Discharge to POTW	Discharge of treated groundwater or treatment waste residuals to a POTW facility via a sanitary sewer. PRASA's wastewater treatment facility is located approximately two miles from the Site.	Effective if there are sanitary sewers in the vicinity of the Site and treated water meets wastewater treatment facility requirements and intake capacity.	Discharge to sanitary sewers would be implementable using available construction resources if sanitary system is present near the Site. Discharged water may require pre-treatment to meet the facility acceptance requirements. Discharge technology must be combined with extraction and ex-situ treatment.	Low capital costs. Medium O&M costs.	Yes	Yes

Note:
Highlighted rows indicate technology eliminated from further evaluation; however, technologies can be reconsidered during the FS if additional information suggest potential applicability as part of a remedial alternative.

Legend:
PREQB - Puerto Rico Environmental Quality Board
PRWQS - Puerto Rico Water Quality Standards
CSM - conceptual site model
POTW - publicly owned treatment works
UIC - underground injection control
NAPL - non aqueous phase liquid
PRG - preliminary remediation goal
SVE - soil vapor extraction
PCE - tetrachloroethene
cis-1,2-DCE - cis-1,2-dichloroethene
1,1-DCE - 1,1-dichloroethene
VC - vinyl chloride
°F - degree Fahrenheit
°C - degree celsius
bgs - below ground surface
EPA - United States Environmental Protection Agency
NPDES - National Pollutant Discharge Elimination System
PRASA - Puerto Rico Aqueduct and Sewer Authority

Table 4-1a
Summary of Comparative Analysis of IDC Soil Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE IDC-S1 No Action	ALTERNATIVE IDC-S2 Containment	ALTERNATIVE IDC-S3 Soil Vapor Extraction; Containment
Summary of Components	None	■ Pre-design investigation and remedial design ■ Cap installation ■ Cap monitoring and maintenance ■ Five-year reviews	■ Pre-design investigation and remedial design ■ Building modification ■ Pilot study ■ Soil vapor extraction ■ Cap installation ■ Operations and maintenance ■ Treatment performance evaluation ■ Site restoration ■ Five-year review
Overall Protection of Human Health and the Environment	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable range. Vapor intrusion risks would be addressed separately from this FS. This alternative would not stop the leaching of contaminants in the soil to the groundwater and hence could result in groundwater contamination under IDC.	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable risk range. Vapor intrusion risks would be addressed separately from this FS. This alternative would reduce the long-term impact to the groundwater by inhibiting rainwater infiltration and thereby, reducing the mass of contaminants leaching into the groundwater. Soil vapor monitoring and, if necessary, installation of the vapor mitigation system would mitigate risks from vapor intrusion.	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable range. This alternative would reduce the long-term impact to the groundwater by removing contaminant mass to the extent practicable and also inhibiting rainwater infiltration and thereby, reducing the mass of contaminants leaching into the groundwater. Soil vapor monitoring and, if necessary, installation of the vapor mitigation system would mitigate risks from vapor intrusion.
Compliance with ARARs	This alternative would not achieve the PRGs. Since no action is performed, location-specific or action-specific ARARs are not applicable.	There are no Federal chemical-specific ARARs for soil. This alternative would comply with EPA's vapor intrusion screen levels, and location-specific and action-specific ARARs.	There are no Federal chemical-specific ARARs for soil. This alternative would comply with EPA's vapor intrusion screen levels, and location-specific and action-specific ARARs.
Long-term Effectiveness and Permanence	This alternative could not be considered a permanent remedy. It would not have long-term effectiveness. This alternative would not provide any mechanism to monitor the migration of contaminants and the migration of contaminants into the groundwater would not be mitigated.	This alternative could be effective in the long-term. The cap would need regular maintenance in perpetuity and contaminant concentrations under the cap would only degrade slowly.	There are uncertainties regarding how effective unenhanced SVE will be in the clayey soil matrix. Clay can swell with moisture and the SVE system may not be effective at promoting back-diffusion into the fractures. Furthermore, the cap would need to be regularly maintained.

Table 4-1a
Summary of Comparative Analysis of IDC Soil Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE IDC-S1 No Action	ALTERNATIVE IDC-S2 Containment	ALTERNATIVE IDC-S3 Soil Vapor Extraction; Containment
Reduction of Toxicity/ Mobility/Volume (T/M/V) Through Treatment	No reduction of contaminant T/M/V through treatment would be achieved under this alternative, since no action would be taken. However, gradual reductions in contaminant mass may occur through degradation, volatilization and leaching.	This alternative would reduce the mobility of the contamination by limiting rainwater infiltration which is the driving leaching mechanism. It would not reduce toxicity or volume.	SVE would reduce T/M/V of the contamination through treatment and the cap would reduce mobility of the contamination. It is uncertain how much of the contaminant mass would be removed through the SVE treatment.
Short-term Effectiveness	Since no remedial action would be implemented, this alternative would not have any short-term impact.	This alternative would include limited site work and would cause minor impacts to the workers and surrounding buildings.	This alternative would have some short-term impacts for several years or potentially more than 10 years, since the wells, piping and equipment associated with the remediation would occupy space on Site, and the operation of a compressor would generate noise. Furthermore, the building would need to be modified for drill rig access. Impact to site workers is expected to be minimal, and the alternative is not expected to result in short-term adverse impacts to the environment.
Implementability	This alternative would be easy to implement since no action would be taken.	This alternative is technically implementable with available equipment, contractors, and materials in Puerto Rico.	It is uncertain to what extent any building modification is implementable. Due to the low permeable soil at the Site, the achievable air flow rate induced by applied vacuum under natural conditions may be limited. A pilot study would be conducted to determine implementability.
Present Worth with Discounting	$0	$205,000	$1.8 million

Table 4-1b
Summary of Comparative Analysis of Ramallo Soil Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE R-S1 No Action	ALTERNATIVE R-S2 Containment	ALTERNATIVE R-S3 Soil Vapor Extraction and Thermal Treatment; Excavation; Off-site Disposal; and Containment	ALTERNATIVE R-S4 In situ Chemical Treatment; and Containment
Summary of Components	None	■ Pre-design investigation and remedial design ■ Cap installation ■ Cap monitoring and maintenance ■ Five-year reviews	■ Pre-design investigation and remedial design ■ Excavation and off-site disposal ■ Soil vapor extraction and thermal treatment system installation ■ Cap installation ■ Operations and decommissioning ■ Treatment performance evaluation ■ Institutional Controls ■ Site restoration ■ Five-year review	■ Pre-design investigation and remedial design ■ Treatability study ■ Hydraulic fracturing and emplacement of amendment ■ Capping ■ Five-year reviews
Overall Protection of Human Health and the Environment	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable range. Vapor intrusion risks would be addressed separately from this FS. This alternative would not stop the continue leaching of contaminants in the soil to the groundwater and hence the contaminants could continue to impact the groundwater.	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable risk range. Vapor intrusion risks would be addressed separately from this FS. This alternative would reduce the long-term impact of the contaminants in the vadose zone to the underlying groundwater by inhibiting rainwater infiltration and thereby, reducing the mass flux of contaminants leaching into the groundwater. Soil vapor monitoring and, if necessary, installation of the vapor mitigation system would mitigate risks from vapor intrusion.	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable risk range. This alternative would reduce the long-term impact to the groundwater by reducing the contamination in the vadose zone through excavating the contaminated surface soil, followed by fracturing and soil vapor extraction. It also inhibits rainwater infiltration and thereby, reduces the mass flux of residual contaminants leaching into the groundwater. Soil vapor monitoring and, if necessary, installation of the vapor mitigation system would mitigate risks from vapor intrusion.	The human health and ecological risks due to direct contact with site-related contaminants are within EPA's acceptable risk range. This alternative would reduce the long-term impact to the groundwater by treatment of contamination in situ. It also inhibits rainwater infiltration and thereby, reduces the mass flux of residual contaminants leaching into the groundwater. Soil vapor monitoring and, if necessary, installation of the vapor mitigation system would mitigate risks from vapor intrusion.
Compliance with ARARs	There are no Federal chemical-specific ARARs for soil. Since no action is performed, location-specific or action-specific ARARs would not be applicable.	There are no Federal chemical-specific ARARs for soil. This alternative would comply with EPA's soil vapor intrusion screening levels, and location-specific and action-specific ARARs.	There are no Federal chemical-specific ARARs for soil. This alternative would comply with EPA's soil vapor intrusion screening levels, and location-specific and action-specific ARARs.	There are no Federal chemical-specific ARARs for soil. This alternative would comply with EPA's soil vapor intrusion screening levels, and location-specific and action-specific ARARs.

Table 4-1b
Summary of Comparative Analysis of Ramallo Soil Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE R-S1 No Action	ALTERNATIVE R-S2 Containment	ALTERNATIVE R-S3 Soil Vapor Extraction and Thermal Treatment; Excavation; Off-site Disposal; and Containment	ALTERNATIVE R-S4 In situ Chemical Treatment; and Containment
Long-term Effectiveness and Permanence	This alternative could not be considered a permanent remedy. It would not have long-term effectiveness. This alternative would not provide any mechanism to monitor the migration of contaminants and the migration of contaminants into the groundwater would not be mitigated.	This alternative could be effective in the long-term. It needs to be regularly maintained and contaminant concentrations under the cap would only degrade slowly.	Excavation and off-site disposal of highly contaminated surface soil would provide permanence and long-term effectiveness. Heating of the clayey vadose zone is expected to remove significant mass contamination from the clay. Furthermore, the cap needs to be regularly maintained.	This alternative would be effective in the long-term and would be permanent. In situ treatment would remove contaminant mass from the highly contaminated hotspot and would reduce contaminant mass. Since contaminants have migrated into the pore matrix of the clayey soil, it is uncertain how much of the contaminant mass would be removed. Furthermore, the cap needs to be regularly maintained.
Reduction of Toxicity/ Mobility/Volume (T/M/V) Through Treatment	No reduction of contaminant T/M/V through treatment would be achieved under this alternative, since no action would be taken. However, gradual reductions in contaminant mass may occur through degradation, volatilization and leaching.	This alternative would reduce the mobility of the contamination by limiting rainwater infiltration which is the driving leaching mechanism. It would not reduce toxicity or volume.	Excavation will reduce T/M/V of the contamination. SVE and thermal treatment would reduce T/M/V of the contamination through treatment and the cap would reduce mobility of the contamination.	In situ treatment would reduce the toxicity and volume of contamination in the treatment zone since the contamination would be transformed to less toxic chemicals. Because the in situ chemical treatment is placed by fracturing, it could increase mobility of the contamination but the fractures would be filled with amendment which would make them reactive zones to further degrade the contamination.
Short-term Effectiveness	Since no remedial action would be implemented, this alternative would not have any short-term impact.	This alternative would include limited site work and would cause minor impacts to the workers and surrounding buildings.	This alternative would have some short-term impacts for approximately one year because of the operation of the heating and SVE system. The operation of a compressor would generate noise. A health and safety plan would be developed, approved by EPA, and properly implemented. PPE and proper monitoring and emission control devices would be used. The impact to Site workers is expected to be minimal.	This alternative would include substantial site work and would cause impacts to the workers and surrounding communities during the amendment emplacement phase and excavation phase. Use of PPE by workers during activities would minimize contaminant exposure. The impact to Site workers is expected to be minimal.

Table 4-1b
Summary of Comparative Analysis of Ramallo Soil Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE R-S1 No Action	ALTERNATIVE R-S2 Containment	ALTERNATIVE R-S3 Soil Vapor Extraction and Thermal Treatment; Excavation; Off-site Disposal; and Containment	ALTERNATIVE R-S4 In situ Chemical Treatment; and Containment
Implementability	This alternative would be easy to implement since no action would be taken.	This alternative is technically implementable with available equipment, contractors, and materials in Puerto Rico.	Excavated hazardous waste would need to be disposed in a RCRA Subtitle C landfill, which is lacking in Puerto Rico. The waste would need to be containerized and shipped to the US mainland. For the excavation, SVE, and thermal treatment, experienced vendors could be procured and thermal remediation and SVE equipment is commercially available.	The fracturing and emplacement of the chemical treatment is implementable; however, since bioremediation is an innovative technology, it would require bench and pilot testing prior to implementation. Existing infrastructure may inhibit the optimal layout of the remediation system. Capping is implementable. It would require maintenance over the long-term and it is uncertain of this maintenance is implementable.
Present Worth with Discounting	$0	$369,000	$3.7 million	$1.9 million

Table 4-2
Summary of Comparative Analysis of Groundwater Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

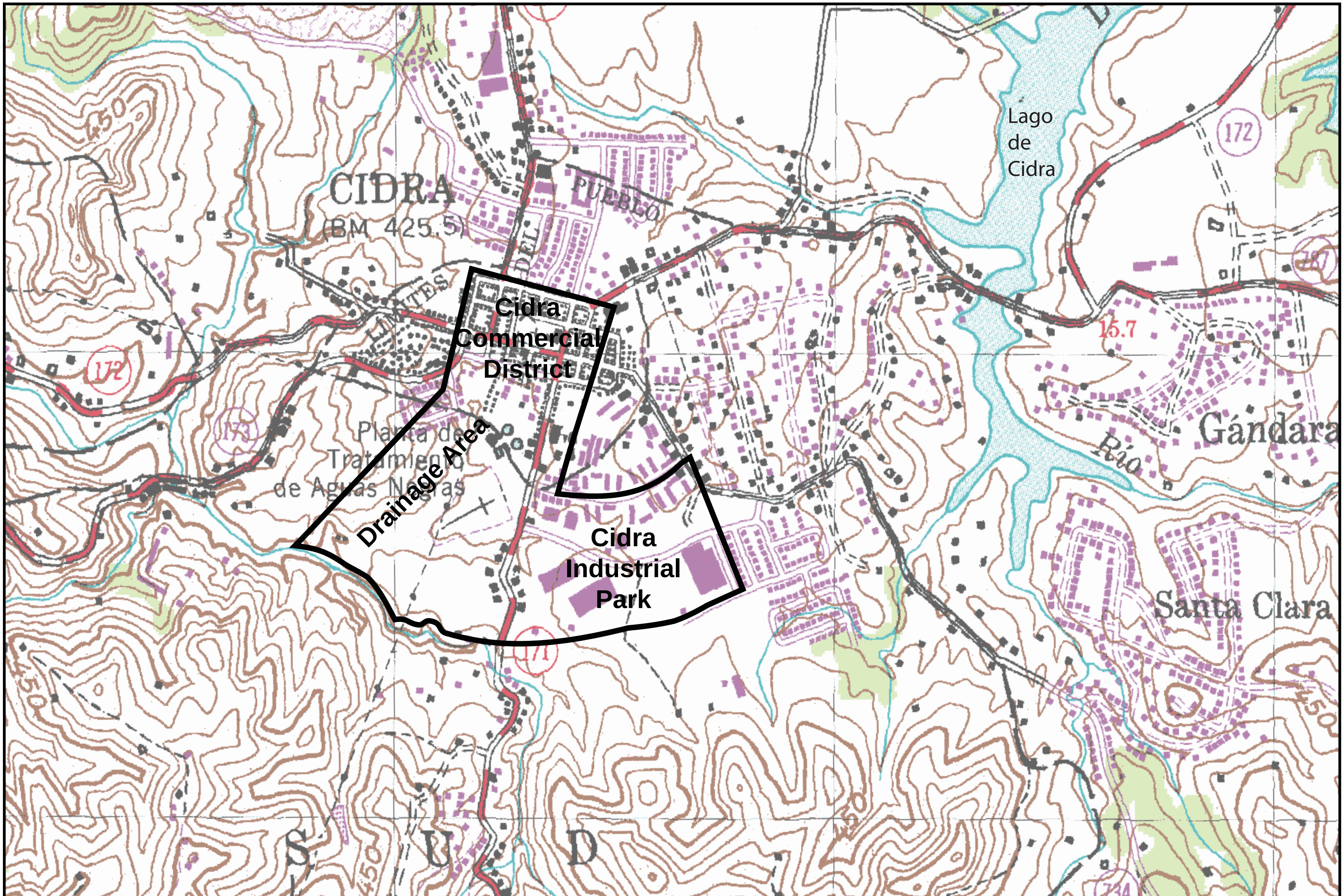
EVALUATION CRITERION	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 3 Optimized Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 4 In Situ Treatment and Long-term Monitoring
Summary of Components	None	■ Pre-design investigation and remedial design ■ Institutional Controls ■ Long-term Monitoring ■ Groundwater Modeling ■ Remedial Design ■ Groundwater Extraction Wells ■ Ex situ treatment system ■ Groundwater discharge ■ Operation and Maintenance ■ Treatment performance monitoring	■ Pre-design investigation and remedial design ■ Institutional Controls ■ Long-term Monitoring ■ Groundwater Modeling ■ Remedial Design ■ Groundwater Extraction Wells at Optimized Locations ■ Ex situ treatment system ■ Groundwater discharge ■ Operation and Maintenance ■ Treatment performance monitoring	■ Pre-design investigation and remedial design ■ Institutional Controls ■ Long-term Monitoring ■ Groundwater Modeling ■ Remedial Design ■ Injection of treatment chemicals near source area ■ Treatment performance monitoring ■ PRB, if deemed necessary
Overall Protection of Human Health and the Environment	This alternative would not eliminate any exposure pathways or reduce the level of human health risk and therefore would not provide protection to human health and the environment.	Pumping and treatment would reduce the plume size and contaminant concentrations in the aquifer over time. Institutional controls would prevent potential human exposure to groundwater contamination until the PRGs are met. Long-term monitoring would monitor the reduction in contaminant concentrations over time.	Pumping and treatment would reduce the plume size and contaminant concentrations in the aquifer over time. Institutional controls would prevent potential human exposure to groundwater contamination until the PRGs are met. Long-term monitoring would monitor the reduction in contaminant concentrations over time.	In situ treatment would destroy the contaminant mass in the aquifer. Institutional controls would prevent potential human exposure to groundwater contamination until the PRGs are met. Long-term monitoring would monitor the reduction in contaminant concentrations over time.
Compliance with ARARs	This alternative would not achieve chemical-specific ARARs for groundwater. Since no action is performed, location-specific or action-specific ARARs would not be applicable.	It is anticipated that the PRGs would be met in the future using this alternative. Location-specific and action-specific ARARs would be met through appropriate permitting and following proper health and safety procedures during construction, treatment, and monitoring activities.	It is anticipated that the PRGs would be met in the future using this alternative. Location-specific and action-specific ARARs would be met through appropriate permitting and following proper health and safety procedures during construction, treatment, and monitoring activities.	It is anticipated that the PRGs would be met in the future using this alternative. Location-specific and action-specific ARARs would be met through appropriate permitting and following proper health and safety procedures during construction, treatment, and monitoring activities.

Table 4-2
Summary of Comparative Analysis of Groundwater Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 3 Optimized Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 4 In Situ Treatment and Long-term Monitoring
Long-term Effectiveness and Permanence	Since no action would be implemented to reduce the level of contamination or verify any naturally occurring reduction, it would not have long-term effectiveness. This alternative would not provide any mechanism to monitor the migration of contaminants.	This alternative would be effective and permanent since treatment of contaminated groundwater would be effective when combined with institutional controls and long-term monitoring. Institutional controls would restrict drilling of new drinking water wells. Extraction and treatment of contaminated groundwater would create an inward gradient that would limit downgradient migration of the contaminants and also accelerate the cleanup of the affected area. It is expected that groundwater would meet the PRGs in the future.	This alternative would be effective and permanent since treatment of contaminated groundwater would be effective when combined with institutional controls and long-term monitoring. Institutional controls would restrict drilling of new drinking water wells. Extraction and treatment of contaminated groundwater would create an inward gradient that would limit downgradient migration of the contaminants and also accelerate the cleanup of the affected area. It is expected that groundwater would meet the PRGs in the future.	This alternative would be effective and permanent since treatment of contaminated groundwater would be effective when combined with institutional controls and long-term monitoring. Multiple applications of treatment amendment and reactivation of PRB (if necessary) would be required.
Reduction of Toxicity/ Mobility/Volume (T/M/V) Through Treatment	No reduction of contaminant T/M/V through treatment would be achieved under this alternative, since no action would be taken. However, gradual reductions in contaminant mass may occur through degradation, volatilization and leaching.	This alternative would provide reduction of T/M/V through groundwater extraction and treatment.	This alternative would provide reduction of T/M/V through groundwater extraction and treatment.	This alternative would provide some reduction of T/M/V by destroying groundwater contaminants in situ. Active treatment would be within a focused PCE isocontour line determined after the pre-design investigation and passive treatment (i.e., PRB) would be used for areas outside of this focused area, if deemed necessary
Short-term Effectiveness	Since no remedial action would be implemented, this alternative would not have any short-term impact.	Under this alternative, there would be some short-term impacts to remediation workers and the community during construction. Engineering controls would be established to minimize the impact while the use of PPE by workers would minimize exposure.	Under this alternative, there would be some short-term impacts to remediation workers and the community during construction. Engineering controls would be established to minimize the impact while the use of PPE by workers would minimize exposure.	Under this alternative, there would be some short-term impacts to remediation workers and the community during construction. Engineering controls would be established to minimize the impact while the use of PPE by workers would minimize exposure.

Table 4-2
Summary of Comparative Analysis of Groundwater Remedial Action Alternatives
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

EVALUATION CRITERION	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 3 Optimized Groundwater Extraction, Treatment, and Long-term Monitoring	ALTERNATIVE 4 In Situ Treatment and Long-term Monitoring
Implementability	This alternative would be easy to implement since no action would be taken.	Pumping and treatment is a proven technology and would be implementable. Many vendors are available to provide the required equipment and services. All required permits would be obtained.	Pumping and treatment is a proven technology and would be implementable. Many vendors are available to provide the required equipment and services. All required permits would be obtained.	This alternative could be implemented using readily available vendors after land use agreements and discharge permits have been obtained.
Present Worth with Discounting	$0	$9.4 million	$8.8 million	$7.4 million



Source USGS 7.5 Minute Series Topographic Map, Comerio Quadrangle, Puerto Rico

Site Area

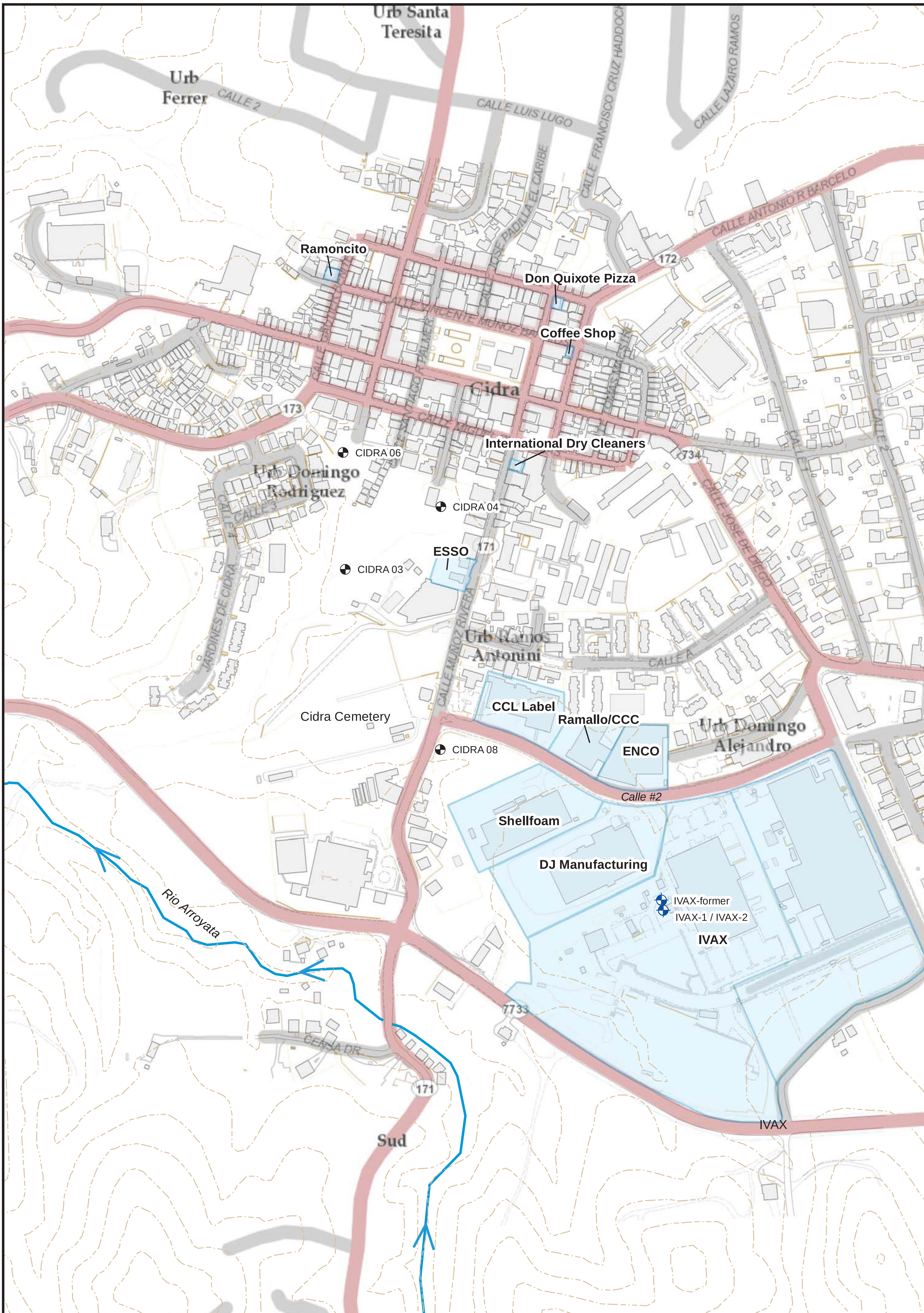
N

approximate scale

0 0.25 0.5 miles

Figure 1-1
Site Location Map
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

R2-0008953



Legend

- Cidra Public Supply Well (out of service)
- Industrial Supply Well
- Topographic contour line (10 meter intervals)
- Rio Arroyata flow direction

Feet
0 100 200 400 600 800

Figure 1-2
Site Map
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008954

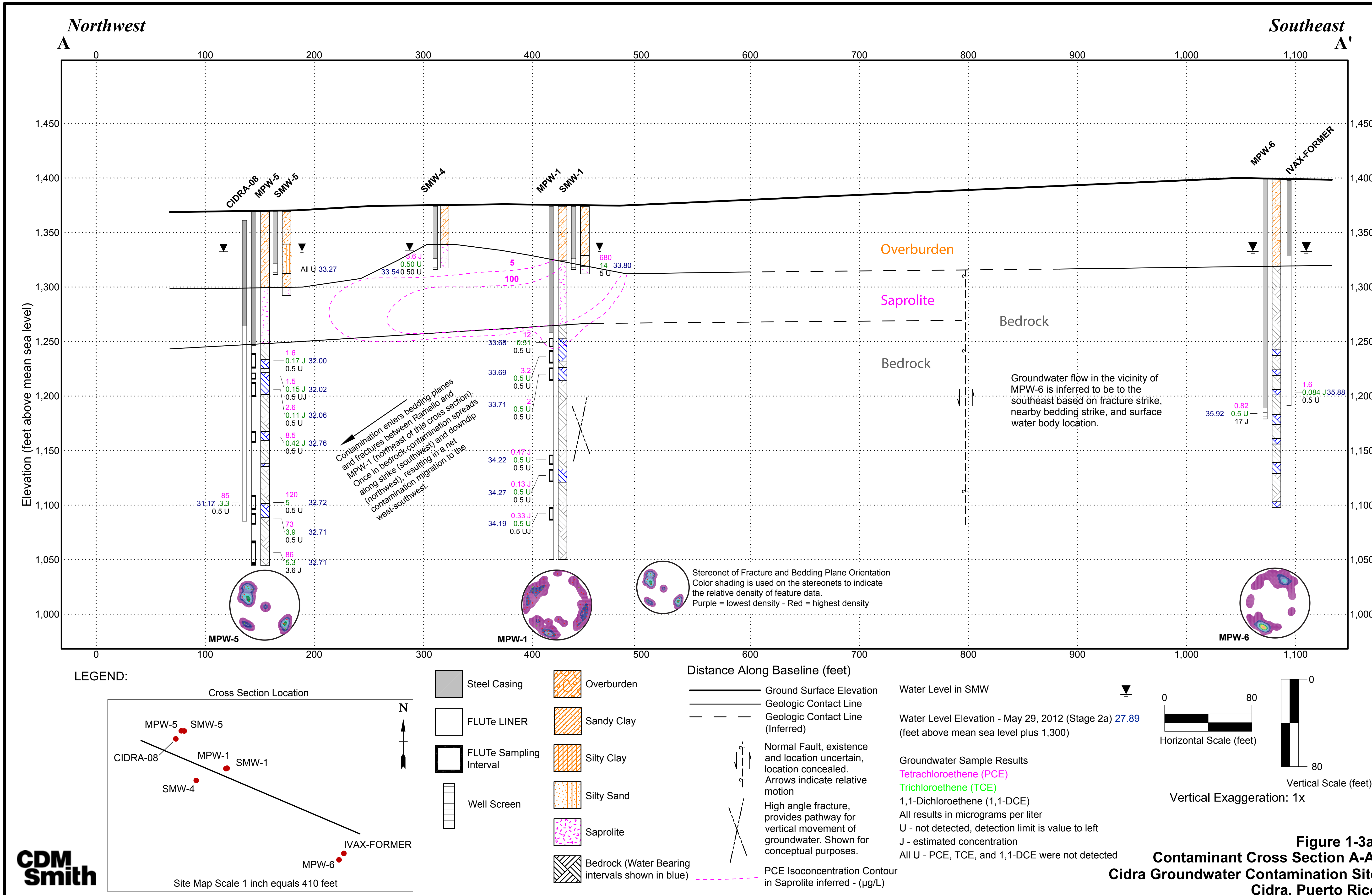


Figure 1-3a
Contaminant Cross Section A-A'
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

STANDARD CROSS SECTION: CIDRA CIDRA-2010.GPJ STANDARD_ENVIRONMENTAL_PROJECT.GDT 8/31/12 REV.

R2-0008955

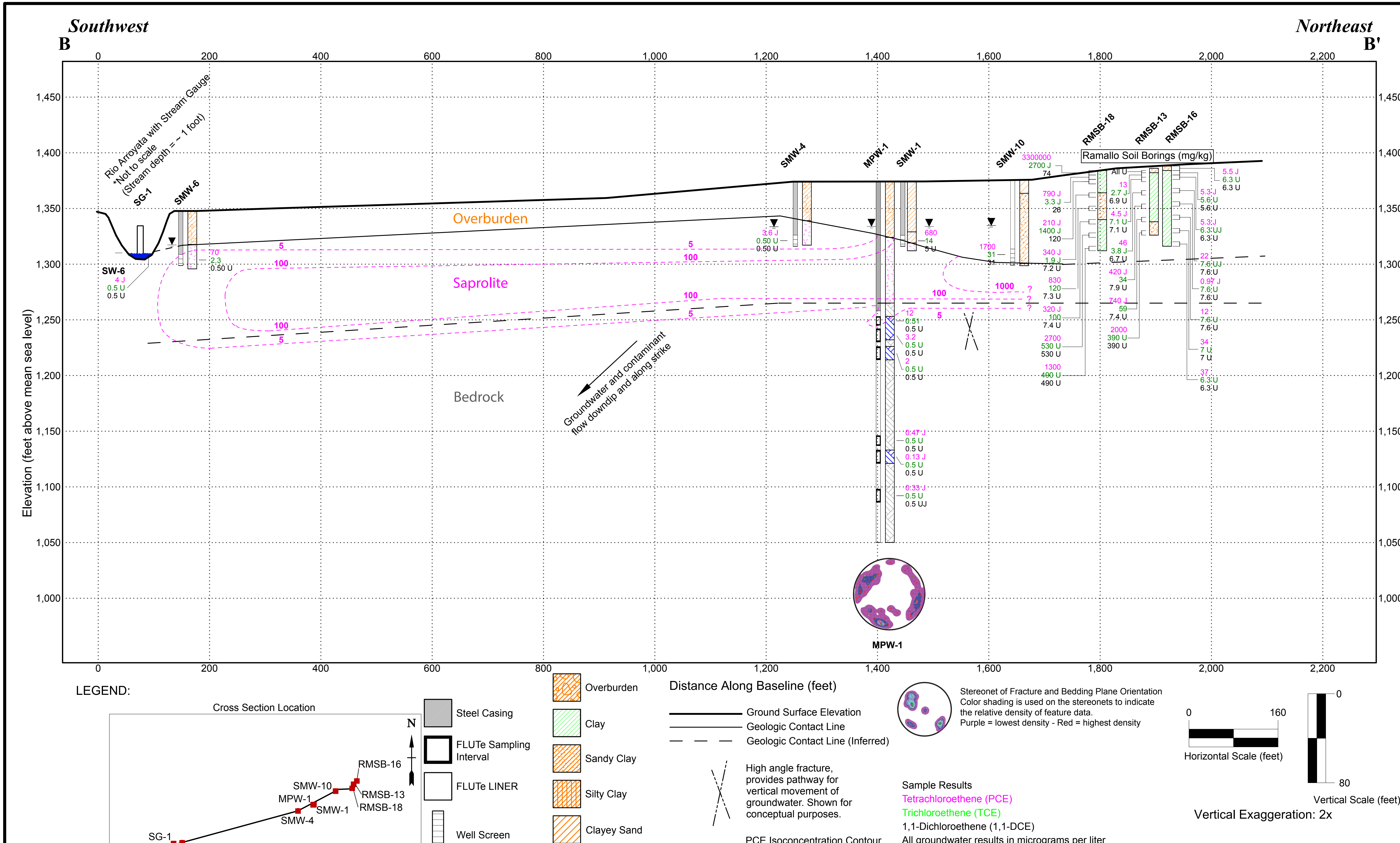


Figure 1-3b
Contaminant Cross Section B-B'
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

STANDARD CROSS SECTION: CIDRA CIDRA-2010.GPJ STANDARD_ENVIRONMENTAL_PROJECT.GDT 9/6/12 REV.

R2-0008956

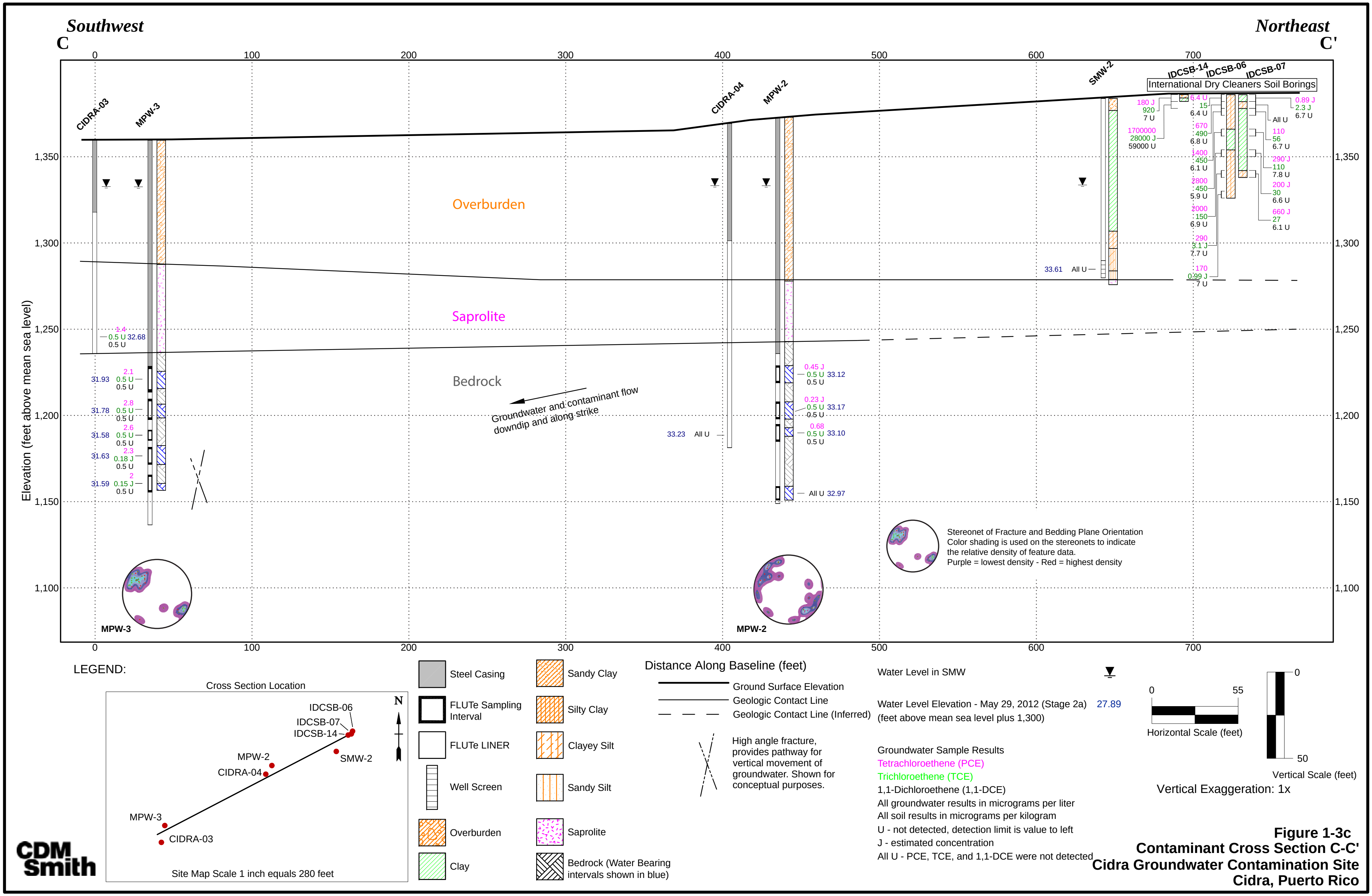


Figure 1-3c
Contaminant Cross Section C-C'
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

STANDARD CROSS SECTION: CIDRA CIDRA-2010.GPJ STANDARD_ENVIRONMENTAL_PROJECT.GDT 9/6/12 REV.

R2-0008957

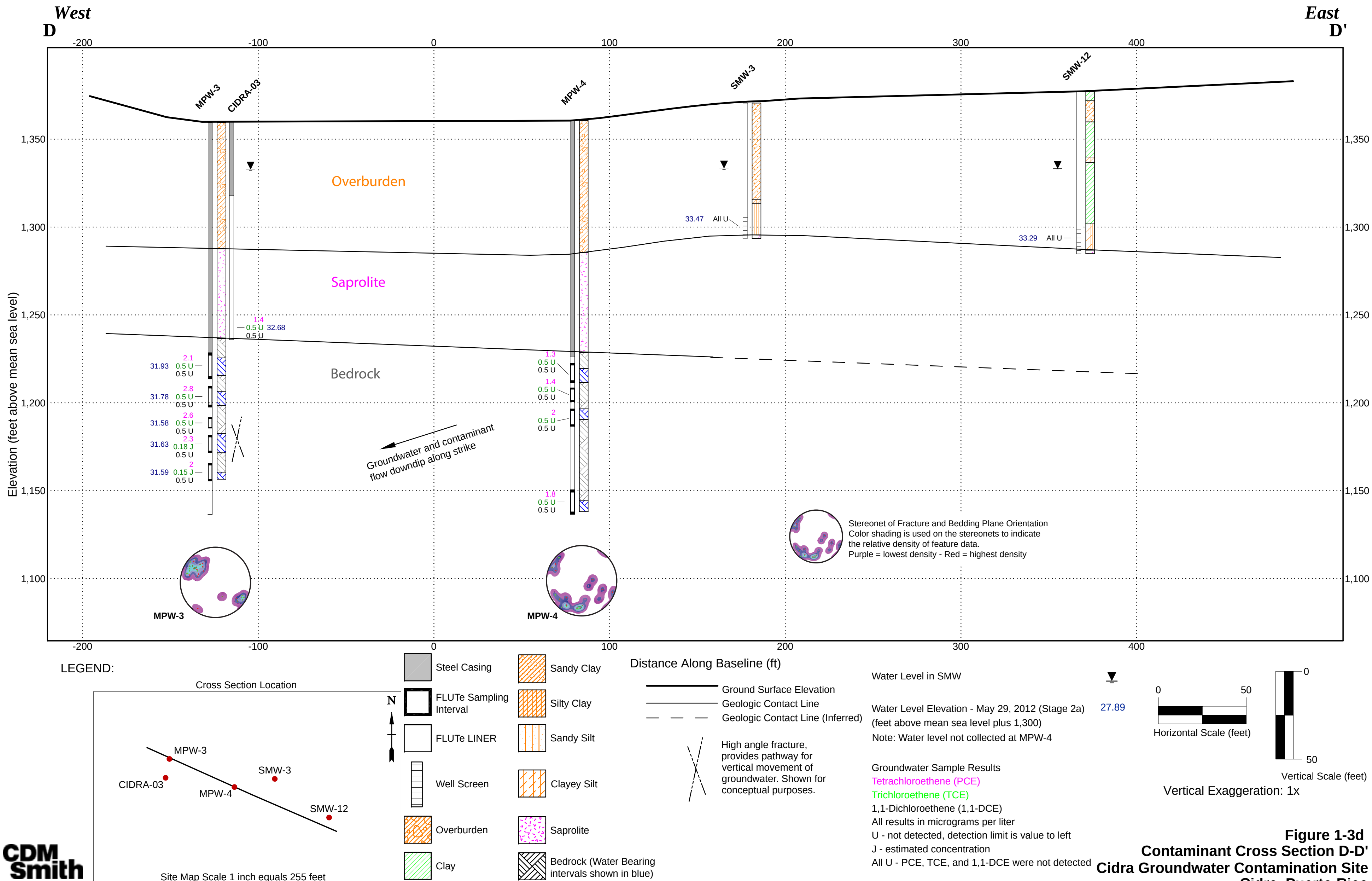


Figure 1-3d
Contaminant Cross Section D-D'
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

STANDARD CROSS SECTION: CIDRA CIDRA-2010.GPJ STANDARD_ENVIRONMENTAL_PROJECT.GDT 9/5/12 REV.

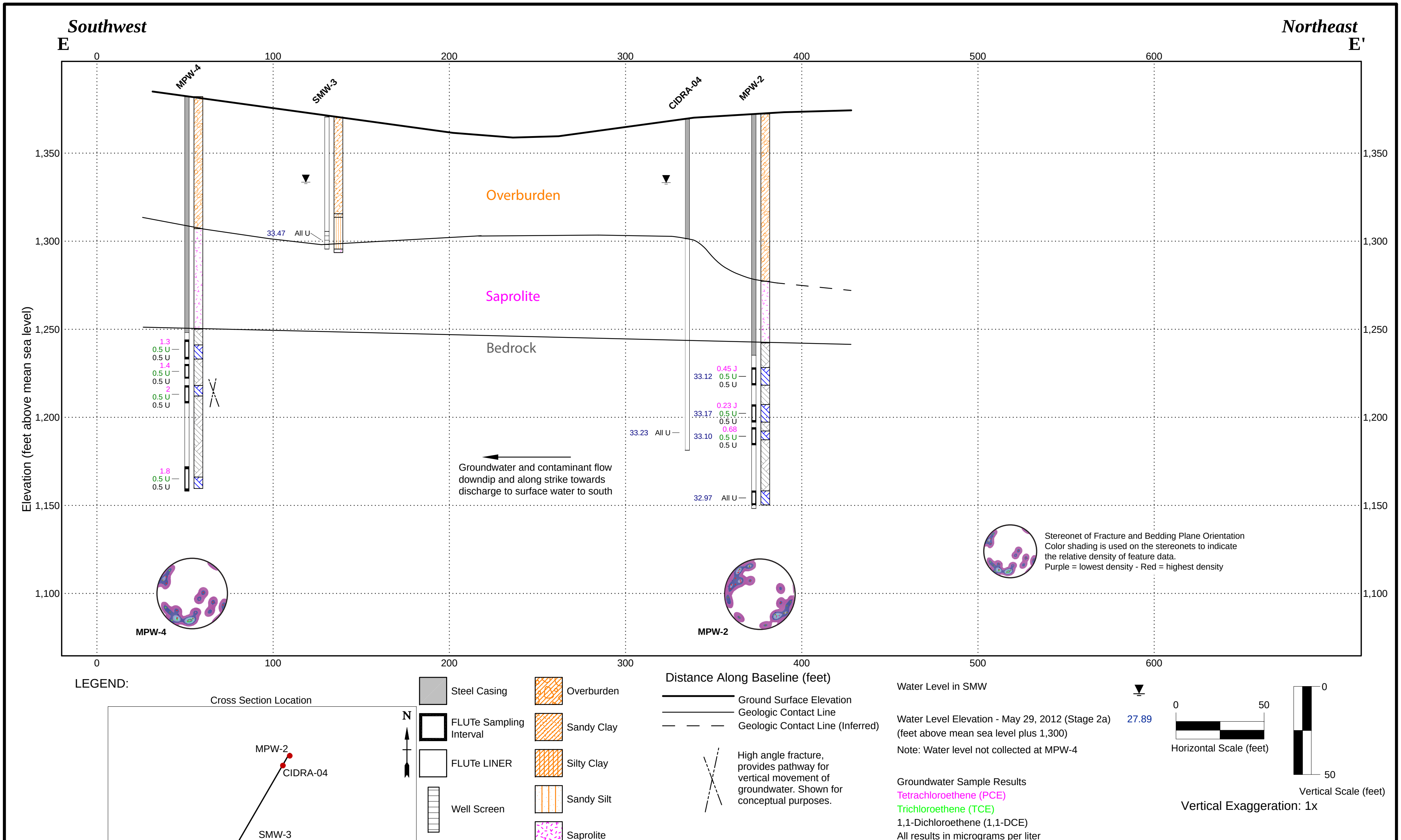
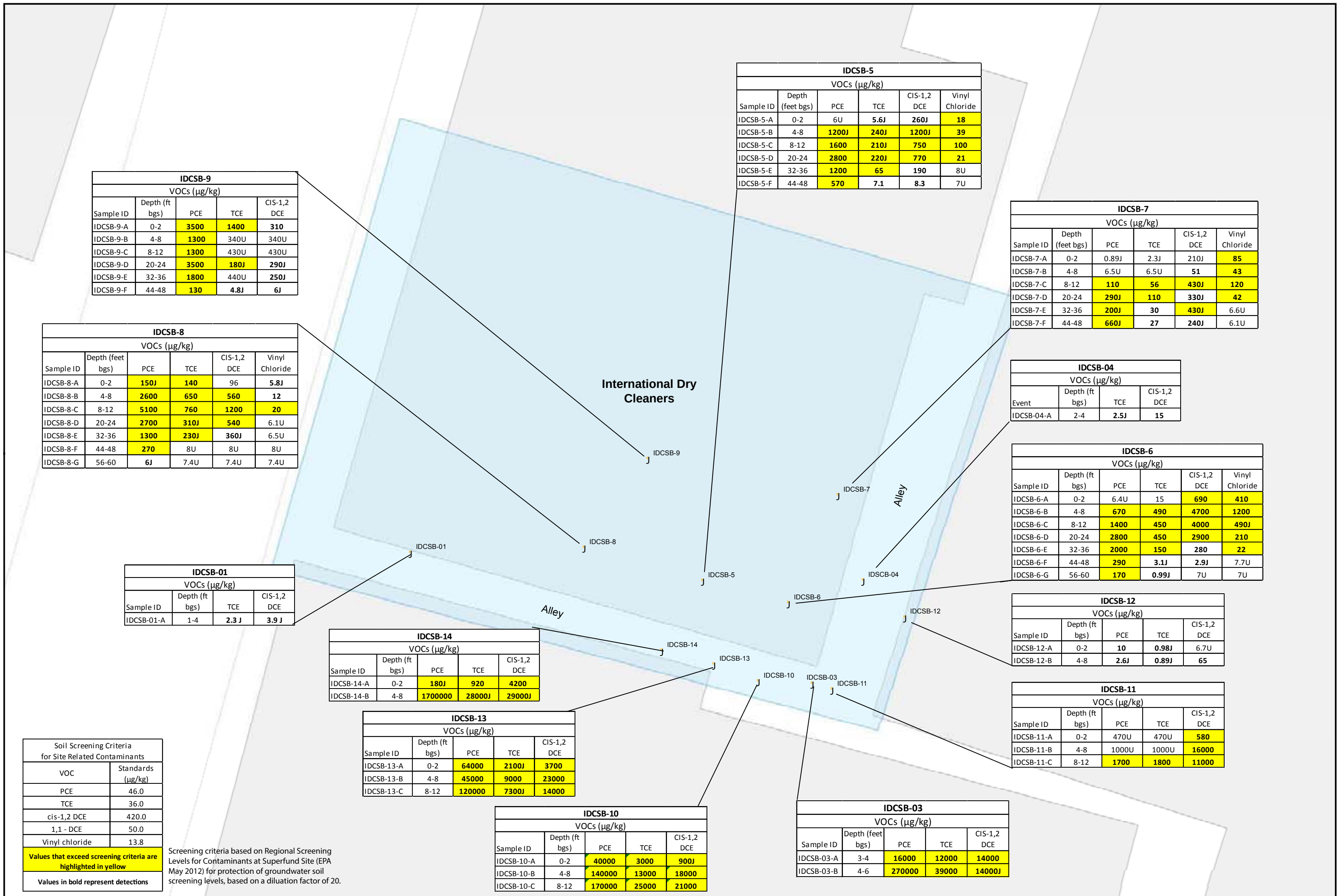


Figure 1-3e
Contaminant Cross Section E-E'
Cidra Groundwater Contamination Site
Cidra, Puerto Rico



IDCSB-9				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-9-A	0-2	**3500**	**1400**	**310**
IDCSB-9-B	4-8	**1300**	340U	340U
IDCSB-9-C	8-12	**1300**	430U	430U
IDCSB-9-D	20-24	**3500**	**180J**	**290J**
IDCSB-9-E	32-36	**1800**	440U	**250J**
IDCSB-9-F	44-48	**130**	**4.8J**	**6J**

IDCSB-8					
VOCs (µg/kg)					
Sample ID	Depth (feet bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-8-A	0-2	**150J**	**140**	96	**5.8J**
IDCSB-8-B	4-8	**2600**	**650**	**560**	**12**
IDCSB-8-C	8-12	**5100**	**760**	**1200**	**20**
IDCSB-8-D	20-24	**2700**	**310J**	**540**	6.1U
IDCSB-8-E	32-36	**1300**	**230J**	**360J**	6.5U
IDCSB-8-F	44-48	**270**	8U	8U	8U
IDCSB-8-G	56-60	**6J**	7.4U	7.4U	7.4U

IDCSB-5					
VOCs (µg/kg)					
Sample ID	Depth (feet bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-5-A	0-2	6U	**5.6J**	**260J**	**18**
IDCSB-5-B	4-8	**1200J**	**240J**	**1200J**	**39**
IDCSB-5-C	8-12	**1600**	**210J**	**750**	**100**
IDCSB-5-D	20-24	**2800**	**220J**	**770**	**21**
IDCSB-5-E	32-36	**1200**	**65**	**190**	8U
IDCSB-5-F	44-48	**570**	**7.1**	**8.3**	7U

IDCSB-7					
VOCs (µg/kg)					
Sample ID	Depth (feet bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-7-A	0-2	0.89J	2.3J	210J	**85**
IDCSB-7-B	4-8	6.5U	6.5U	**51**	**43**
IDCSB-7-C	8-12	**110**	**56**	**430J**	**120**
IDCSB-7-D	20-24	**290J**	**110**	**330J**	**42**
IDCSB-7-E	32-36	**200J**	**30**	**430J**	6.6U
IDCSB-7-F	44-48	**660J**	**27**	**240J**	6.1U

IDCSB-04			
VOCs (µg/kg)			
Event	Depth (ft bgs)	TCE	CIS-1,2 DCE
IDCSB-04-A	2-4	**2.5J**	**15**

IDCSB-6					
VOCs (µg/kg)					
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-6-A	0-2	6.4U	15	**690**	**410**
IDCSB-6-B	4-8	**670**	**490**	**4700**	**1200**
IDCSB-6-C	8-12	**1400**	**450**	**4000**	**490J**
IDCSB-6-D	20-24	**2800**	**450**	**2900**	**210**
IDCSB-6-E	32-36	**2000**	**150**	**280**	**22**
IDCSB-6-F	44-48	**290**	**3.1J**	**2.9J**	7.7U
IDCSB-6-G	56-60	**170**	**0.99J**	7U	7U

IDCSB-01			
VOCs (µg/kg)			
Sample ID	Depth (ft bgs)	TCE	CIS-1,2 DCE
IDCSB-01-A	1-4	**2.3 J**	**3.9 J**

IDCSB-12				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-12-A	0-2	**10**	**0.98J**	6.7U
IDCSB-12-B	4-8	**2.6J**	**0.89J**	**65**

IDCSB-14				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-14-A	0-2	**180J**	**920**	**4200**
IDCSB-14-B	4-8	**1700000**	**28000J**	**29000J**

IDCSB-11				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-11-A	0-2	470U	470U	**580**
IDCSB-11-B	4-8	1000U	1000U	**16000**
IDCSB-11-C	8-12	**1700**	**1800**	**11000**

IDCSB-13				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-13-A	0-2	**64000**	**2100J**	**3700**
IDCSB-13-B	4-8	**45000**	**9000**	**23000**
IDCSB-13-C	8-12	**120000**	**7300J**	**14000**

Soil Screening Criteria for Site Related Contaminants	
VOC	Standards (µg/kg)
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a dilution factor of 20.

IDCSB-10				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-10-A	0-2	**40000**	**3000**	**900J**
IDCSB-10-B	4-8	**140000**	**13000**	**18000**
IDCSB-10-C	8-12	**170000**	**25000**	**21000**

IDCSB-03				
VOCs (µg/kg)				
Sample ID	Depth (feet bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-03-A	3-4	**16000**	**12000**	**14000**
IDCSB-03-B	4-6	**270000**	**39000**	**14000J**

Notes:
Detections are in bold
ft bgs - feet below ground surface
J - estimated value
µg/kg - micrograms per kilograms
U - not detected above the listed detection limit

VOC - volatile organic compound
PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene
SRC - Site Related Contaminants

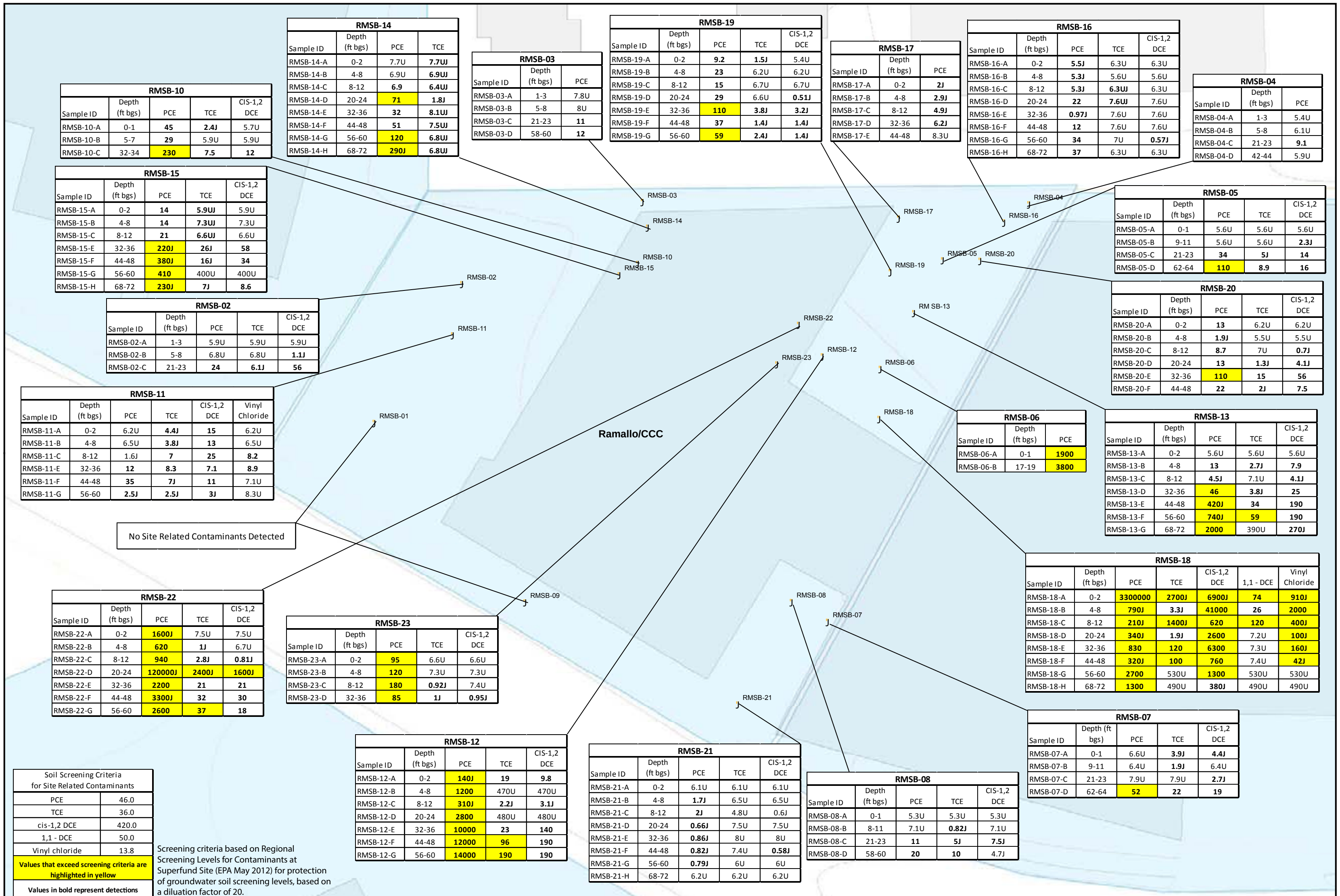
N

0 3.75 7.5 15 22.5 30 Feet

Figure 1-4
Site-Related Contaminant Soil Results - International Dry Cleaners
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008960



RMSB-14

Sample ID	Depth (ft bgs)	PCE	TCE
RMSB-14-A	0-2	7.7U	7.7UJ
RMSB-14-B	4-8	6.9U	6.9UJ
RMSB-14-C	8-12	6.9	6.4UJ
RMSB-14-D	20-24	71	1.8J
RMSB-14-E	32-36	32	8.1UJ
RMSB-14-F	44-48	51	7.5UJ
RMSB-14-G	56-60	120	6.8UJ
RMSB-14-H	68-72	290J	6.8UJ

RMSB-03

Sample ID	Depth (ft bgs)	PCE
RMSB-03-A	1-3	7.8U
RMSB-03-B	5-8	8U
RMSB-03-C	21-23	11
RMSB-03-D	58-60	12

RMSB-19

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-19-A	0-2	9.2	1.5J	5.4U
RMSB-19-B	4-8	23	6.2U	6.2U
RMSB-19-C	8-12	15	6.7U	6.7U
RMSB-19-D	20-24	29	6.6U	0.51J
RMSB-19-E	32-36	110	3.8J	3.2J
RMSB-19-F	44-48	37	1.4J	1.4J
RMSB-19-G	56-60	59	2.4J	1.4J

RMSB-17

Sample ID	Depth (ft bgs)	PCE
RMSB-17-A	0-2	2J
RMSB-17-B	4-8	2.9J
RMSB-17-C	8-12	4.9J
RMSB-17-D	32-36	6.2J
RMSB-17-E	44-48	8.3U

RMSB-16

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-16-A	0-2	5.5J	6.3U	6.3U
RMSB-16-B	4-8	5.3J	5.6U	5.6U
RMSB-16-C	8-12	5.3J	6.3UJ	6.3U
RMSB-16-D	20-24	22	7.6UJ	7.6U
RMSB-16-E	32-36	0.97J	7.6U	7.6U
RMSB-16-F	44-48	12	7.6U	7.6U
RMSB-16-G	56-60	34	7U	0.57J
RMSB-16-H	68-72	37	6.3U	6.3U

RMSB-04

Sample ID	Depth (ft bgs)	PCE
RMSB-04-A	1-3	5.4U
RMSB-04-B	5-8	6.1U
RMSB-04-C	21-23	9.1
RMSB-04-D	42-44	5.9U

RMSB-10

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-10-A	0-1	45	2.4J	5.7U
RMSB-10-B	5-7	29	5.9U	5.9U
RMSB-10-C	32-34	230	7.5	12

RMSB-15

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-15-A	0-2	14	5.9UJ	5.9U
RMSB-15-B	4-8	14	7.3UJ	7.3U
RMSB-15-C	8-12	21	6.6UJ	6.6U
RMSB-15-E	32-36	220J	26J	58
RMSB-15-F	44-48	380J	16J	34
RMSB-15-G	56-60	410	400U	400U
RMSB-15-H	68-72	230J	7J	8.6

RMSB-05

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-05-A	0-1	5.6U	5.6U	5.6U
RMSB-05-B	9-11	5.6U	5.6U	2.3J
RMSB-05-C	21-23	34	5J	14
RMSB-05-D	62-64	110	8.9	16

RMSB-02

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-02-A	1-3	5.9U	5.9U	5.9U
RMSB-02-B	5-8	6.8U	6.8U	1.1J
RMSB-02-C	21-23	24	6.1J	56

RMSB-20

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-20-A	0-2	13	6.2U	6.2U
RMSB-20-B	4-8	1.9J	5.5U	5.5U
RMSB-20-C	8-12	8.7	7U	0.7J
RMSB-20-D	20-24	13	1.3J	4.1J
RMSB-20-E	32-36	110	15	56
RMSB-20-F	44-48	22	2J	7.5

RMSB-11

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
RMSB-11-A	0-2	6.2U	4.4J	15	6.2U
RMSB-11-B	4-8	6.5U	3.8J	13	6.5U
RMSB-11-C	8-12	1.6J	7	25	8.2
RMSB-11-E	32-36	12	8.3	7.1	8.9
RMSB-11-F	44-48	35	7J	11	7.1U
RMSB-11-G	56-60	2.5J	2.5J	3J	8.3U

RMSB-06

Sample ID	Depth (ft bgs)	PCE
RMSB-06-A	0-1	1900
RMSB-06-B	17-19	3800

RMSB-13

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-13-A	0-2	5.6U	5.6U	5.6U
RMSB-13-B	4-8	13	2.7J	7.9
RMSB-13-C	8-12	4.5J	7.1U	4.1J
RMSB-13-D	32-36	46	3.8J	25
RMSB-13-E	44-48	420J	34	190
RMSB-13-F	56-60	740J	59	190
RMSB-13-G	68-72	2000	390U	270J

No Site Related Contaminants Detected

RMSB-18

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	1,1 - DCE	Vinyl Chloride
RMSB-18-A	0-2	3300000	2700J	6900J	74	910J
RMSB-18-B	4-8	790J	3.3J	41000	26	2000
RMSB-18-C	8-12	210J	1400J	620	120	400J
RMSB-18-D	20-24	340J	1.9J	2600	7.2U	100J
RMSB-18-E	32-36	830	120	6300	7.3U	160J
RMSB-18-F	44-48	320J	100	760	7.4U	42J
RMSB-18-G	56-60	2700	530U	1300	530U	530U
RMSB-18-H	68-72	1300	490U	380J	490U	490U

RMSB-22

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-22-A	0-2	1600J	7.5U	7.5U
RMSB-22-B	4-8	620	1J	6.7U
RMSB-22-C	8-12	940	2.8J	0.81J
RMSB-22-D	20-24	120000J	2400J	1600J
RMSB-22-E	32-36	2200	21	21
RMSB-22-F	44-48	3300J	32	30
RMSB-22-G	56-60	2600	37	18

RMSB-23

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-23-A	0-2	95	6.6U	6.6U
RMSB-23-B	4-8	120	7.3U	7.3U
RMSB-23-C	8-12	180	0.92J	7.4U
RMSB-23-D	32-36	85	1J	0.95J

RMSB-07

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-07-A	0-1	6.6U	3.9J	4.4J
RMSB-07-B	9-11	6.4U	1.9J	6.4U
RMSB-07-C	21-23	7.9U	7.9U	2.7J
RMSB-07-D	62-64	52	22	19

RMSB-12

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-12-A	0-2	140J	19	9.8
RMSB-12-B	4-8	1200	470U	470U
RMSB-12-C	8-12	310J	2.2J	3.1J
RMSB-12-D	20-24	2800	480U	480U
RMSB-12-E	32-36	10000	23	140
RMSB-12-F	44-48	12000	96	190
RMSB-12-G	56-60	14000	190	190

RMSB-21

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-21-A	0-2	6.1U	6.1U	6.1U
RMSB-21-B	4-8	1.7J	6.5U	6.5U
RMSB-21-C	8-12	2J	4.8U	0.6J
RMSB-21-D	20-24	0.66J	7.5U	7.5U
RMSB-21-E	32-36	0.86J	8U	8U
RMSB-21-F	44-48	0.82J	7.4U	0.58J
RMSB-21-G	56-60	0.79J	6U	6U
RMSB-21-H	68-72	6.2U	6.2U	6.2U

RMSB-08

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-08-A	0-1	5.3U	5.3U	5.3U
RMSB-08-B	8-11	7.1U	0.82J	7.1U
RMSB-08-C	21-23	11	5J	7.5J
RMSB-08-D	58-60	20	10	4.7J

Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a diluation factor of 20.

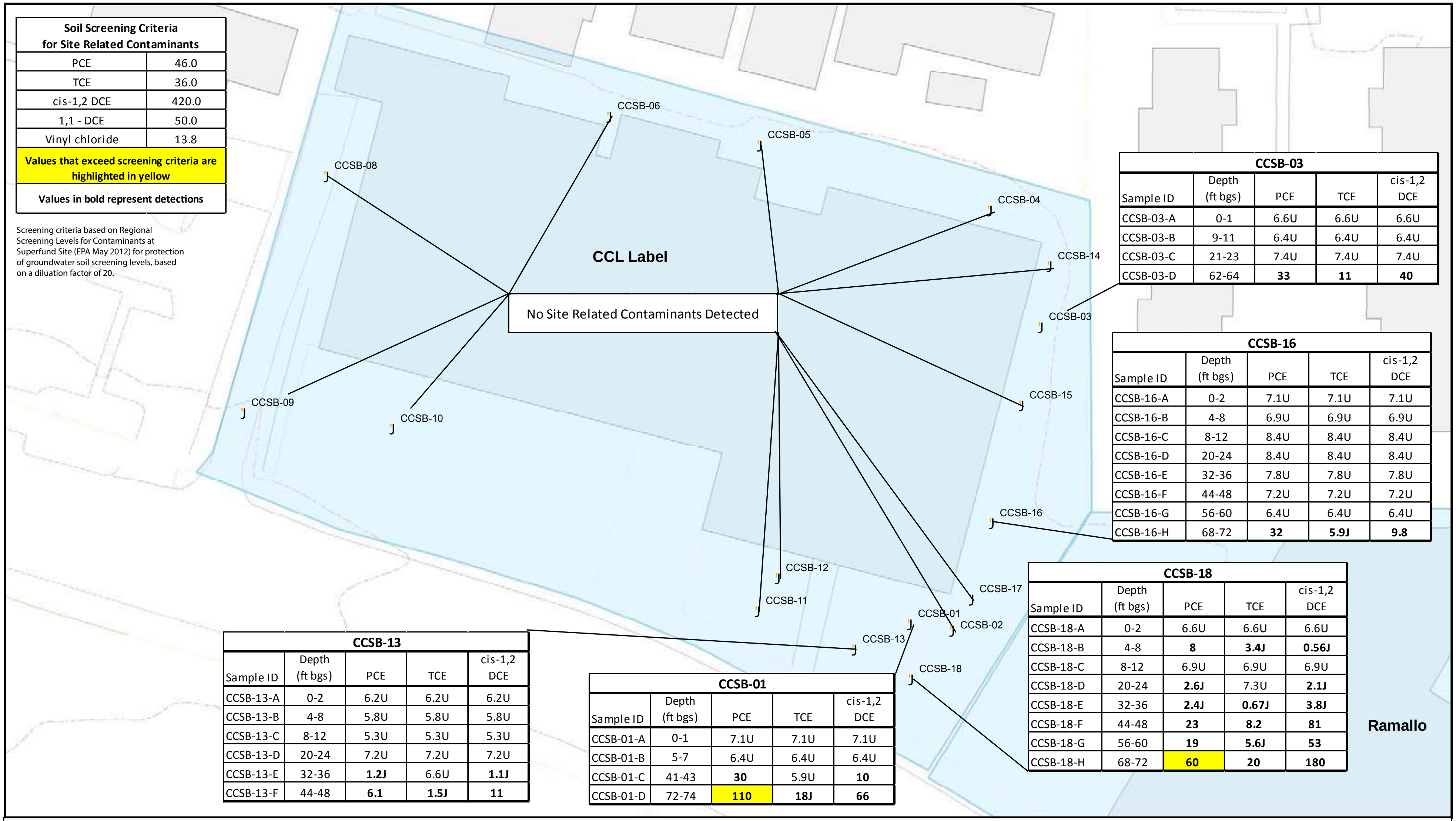
Notes:
All results in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

Figure 1-5
Site-Related Contaminant Soil Results - Ramallo/Cidra Convention Center
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008961



Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8

Values that exceed screening criteria are highlighted in yellow

Values in bold represent detections

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a diluation factor of 20.

CCSB-03

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
CCSB-03-A	0-1	6.6U	6.6U	6.6U
CCSB-03-B	9-11	6.4U	6.4U	6.4U
CCSB-03-C	21-23	7.4U	7.4U	7.4U
CCSB-03-D	62-64	**33**	**11**	**40**

CCSB-16

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
CCSB-16-A	0-2	7.1U	7.1U	7.1U
CCSB-16-B	4-8	6.9U	6.9U	6.9U
CCSB-16-C	8-12	8.4U	8.4U	8.4U
CCSB-16-D	20-24	8.4U	8.4U	8.4U
CCSB-16-E	32-36	7.8U	7.8U	7.8U
CCSB-16-F	44-48	7.2U	7.2U	7.2U
CCSB-16-G	56-60	6.4U	6.4U	6.4U
CCSB-16-H	68-72	**32**	**5.9J**	**9.8**

CCSB-18

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
CCSB-18-A	0-2	6.6U	6.6U	6.6U
CCSB-18-B	4-8	**8**	**3.4J**	**0.56J**
CCSB-18-C	8-12	6.9U	6.9U	6.9U
CCSB-18-D	20-24	**2.6J**	7.3U	**2.1J**
CCSB-18-E	32-36	**2.4J**	**0.67J**	**3.8J**
CCSB-18-F	44-48	**23**	**8.2**	**81**
CCSB-18-G	56-60	**19**	**5.6J**	**53**
CCSB-18-H	68-72	**60**	**20**	**180**

CCSB-13

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
CCSB-13-A	0-2	6.2U	6.2U	6.2U
CCSB-13-B	4-8	5.8U	5.8U	5.8U
CCSB-13-C	8-12	5.3U	5.3U	5.3U
CCSB-13-D	20-24	7.2U	7.2U	7.2U
CCSB-13-E	32-36	**1.2J**	6.6U	**1.1J**
CCSB-13-F	44-48	**6.1**	**1.5J**	**11**

CCSB-01

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
CCSB-01-A	0-1	7.1U	7.1U	7.1U
CCSB-01-B	5-7	6.4U	6.4U	6.4U
CCSB-01-C	41-43	**30**	5.9U	**10**
CCSB-01-D	72-74	**110**	**18J**	**66**

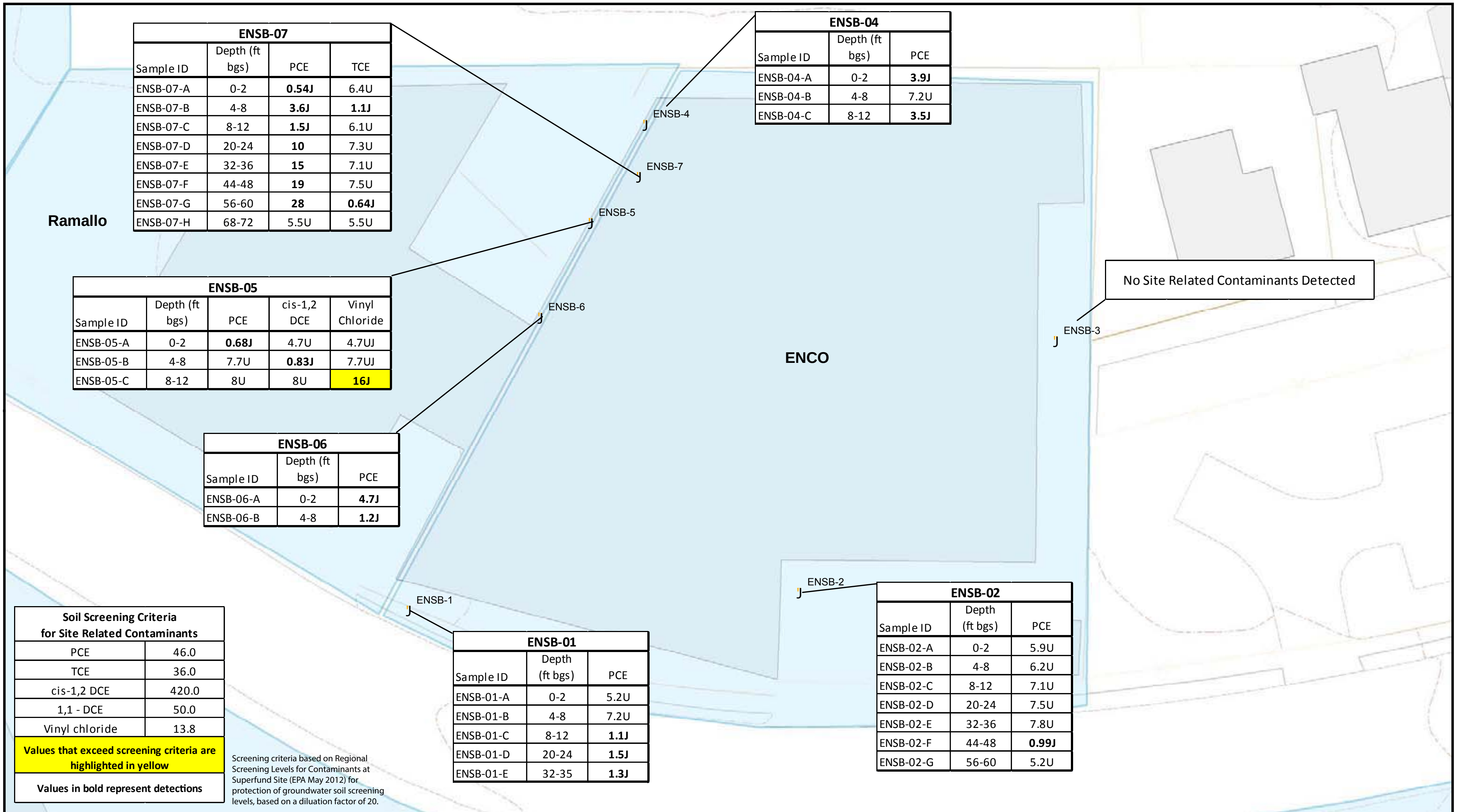
Notes:
All results in micrograms per kilogram (μg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

Figure 1-6
Site-Related Contaminant Soil Results - CCL Label
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008962



ENSB-07			
Sample ID	Depth (ft bgs)	PCE	TCE
ENSB-07-A	0-2	**0.54J**	6.4U
ENSB-07-B	4-8	**3.6J**	**1.1J**
ENSB-07-C	8-12	**1.5J**	6.1U
ENSB-07-D	20-24	**10**	7.3U
ENSB-07-E	32-36	**15**	7.1U
ENSB-07-F	44-48	**19**	7.5U
ENSB-07-G	56-60	**28**	**0.64J**
ENSB-07-H	68-72	5.5U	5.5U

ENSB-04		
Sample ID	Depth (ft bgs)	PCE
ENSB-04-A	0-2	**3.9J**
ENSB-04-B	4-8	7.2U
ENSB-04-C	8-12	**3.5J**

ENSB-05				
Sample ID	Depth (ft bgs)	PCE	cis-1,2 DCE	Vinyl Chloride
ENSB-05-A	0-2	**0.68J**	4.7U	4.7UJ
ENSB-05-B	4-8	7.7U	**0.83J**	7.7UJ
ENSB-05-C	8-12	8U	8U	**16J**

ENSB-06		
Sample ID	Depth (ft bgs)	PCE
ENSB-06-A	0-2	**4.7J**
ENSB-06-B	4-8	**1.2J**

ENSB-01		
Sample ID	Depth (ft bgs)	PCE
ENSB-01-A	0-2	5.2U
ENSB-01-B	4-8	7.2U
ENSB-01-C	8-12	**1.1J**
ENSB-01-D	20-24	**1.5J**
ENSB-01-E	32-35	**1.3J**

ENSB-02		
Sample ID	Depth (ft bgs)	PCE
ENSB-02-A	0-2	5.9U
ENSB-02-B	4-8	6.2U
ENSB-02-C	8-12	7.1U
ENSB-02-D	20-24	7.5U
ENSB-02-E	32-36	7.8U
ENSB-02-F	44-48	**0.99J**
ENSB-02-G	56-60	5.2U

Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

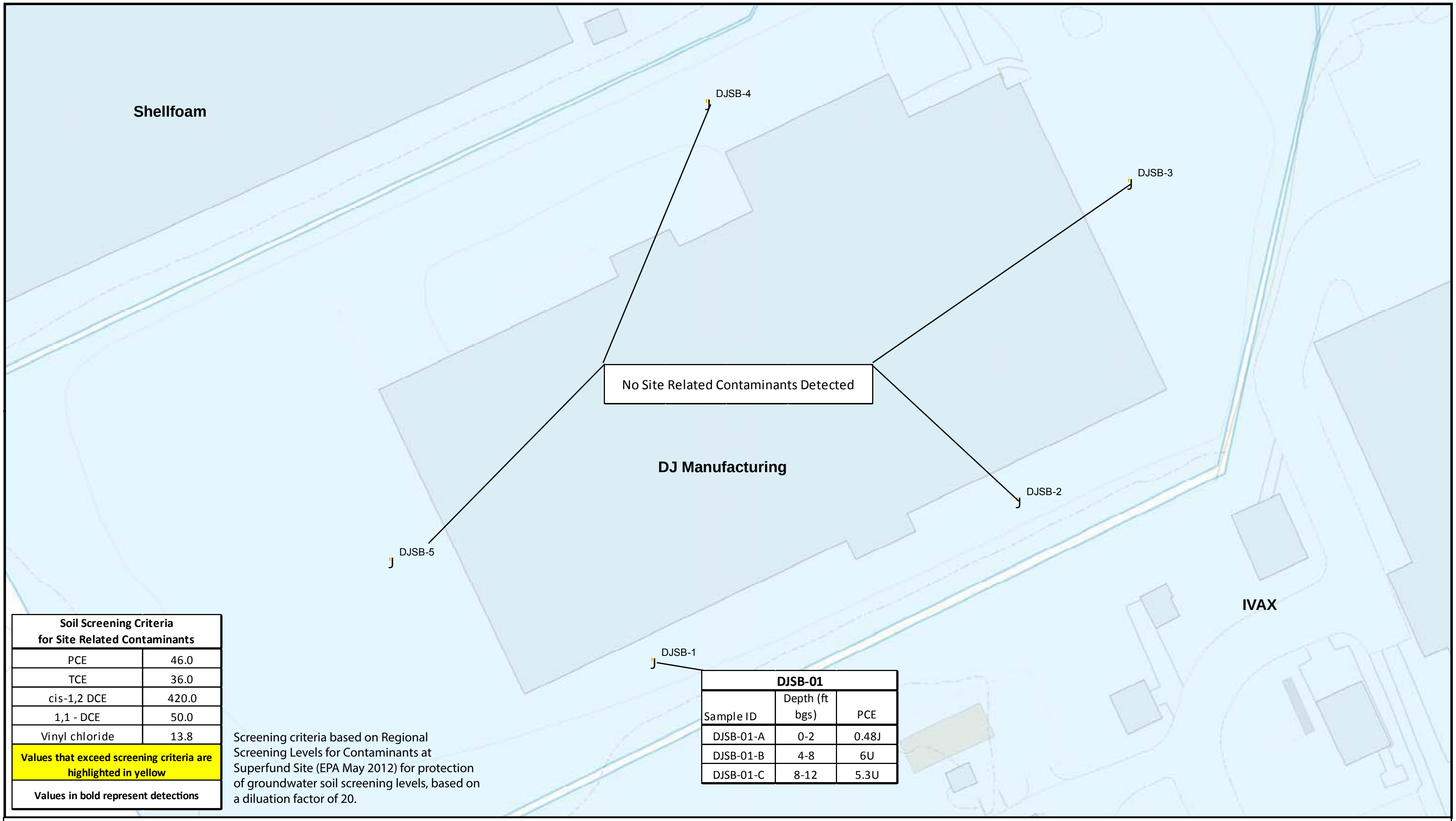
Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a diluation factor of 20.

Notes:
All result in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

Figure 1-7
Site-Related Contaminant Soil Results - ENCO
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith



Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a diluation factor of 20.

DJSB-01		
Sample ID	Depth (ft bgs)	PCE
DJSB-01-A	0-2	0.48J
DJSB-01-B	4-8	6U
DJSB-01-C	8-12	5.3U

Notes:
All results in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

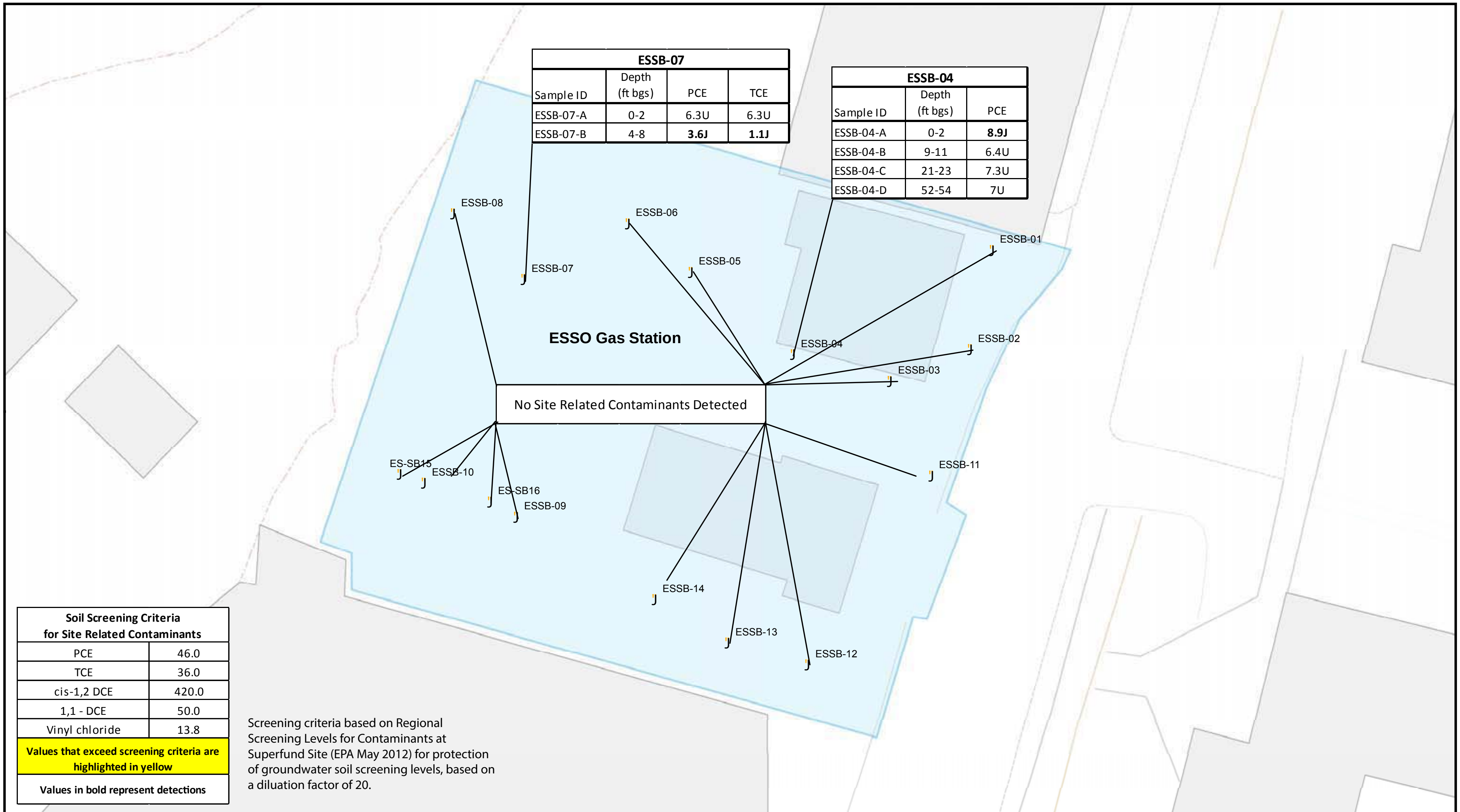
N

0 15 30 60 90 120 Feet

Figure 1-8
Site-Related Contaminant Soil Results - DJ Manufacturing
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008964



ESSB-07			
Sample ID	Depth (ft bgs)	PCE	TCE
ESSB-07-A	0-2	6.3U	6.3U
ESSB-07-B	4-8	**3.6J**	**1.1J**

ESSB-04		
Sample ID	Depth (ft bgs)	PCE
ESSB-04-A	0-2	**8.9J**
ESSB-04-B	9-11	6.4U
ESSB-04-C	21-23	7.3U
ESSB-04-D	52-54	7U

Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a dilution factor of 20.

Notes:
All results in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

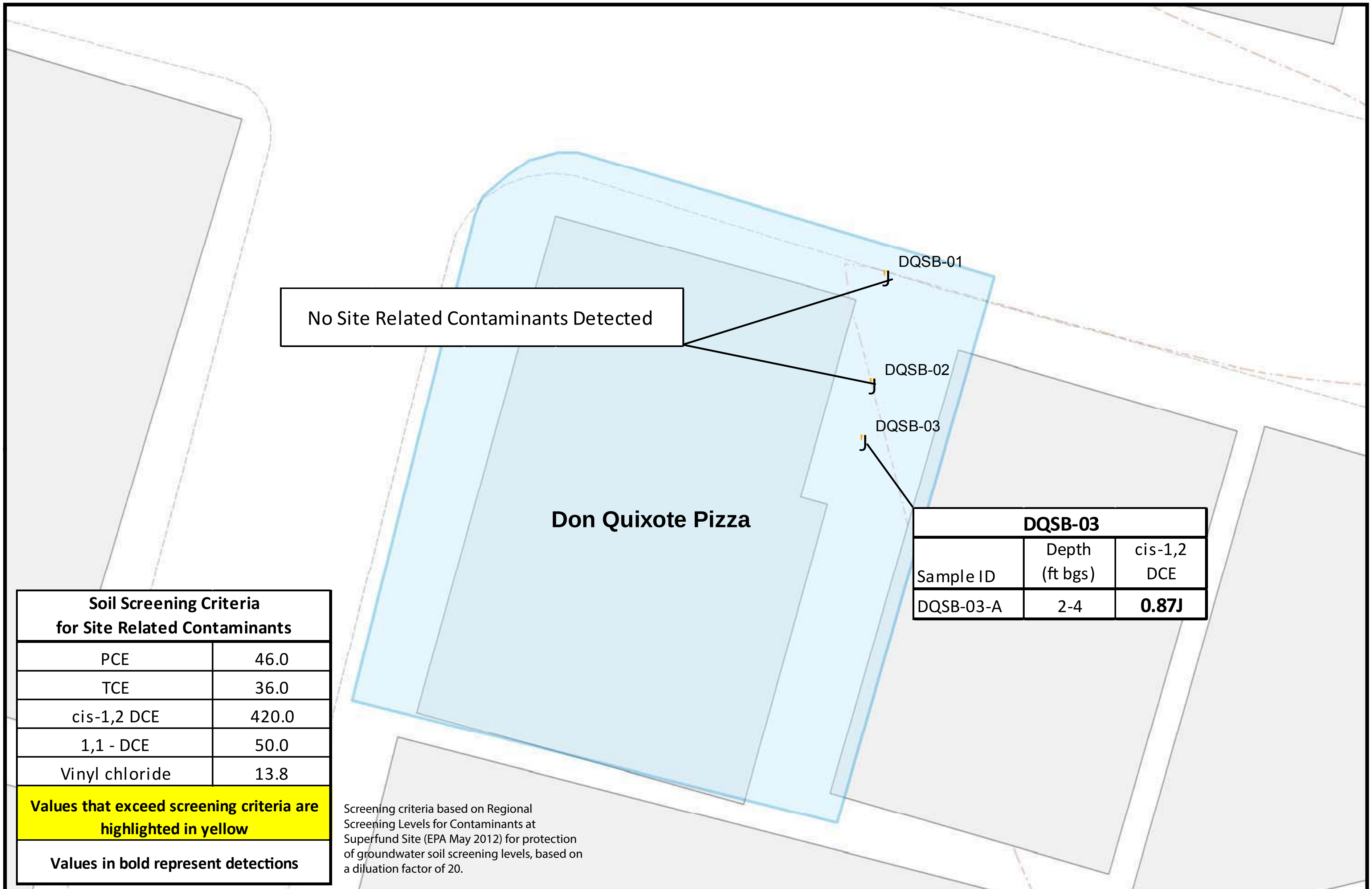
N

Feet
0 5 10 20 30 40

Figure 1-9
Site-Related Contaminant Soil Results - ESSO Gas Station
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008965



DQSB-03		
Sample ID	Depth (ft bgs)	cis-1,2 DCE
DQSB-03-A	2-4	**0.87J**

Soil Screening Criteria for Site Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

Screening criteria based on Regional Screening Levels for Contaminants at Superfund Site (EPA May 2012) for protection of groundwater soil screening levels, based on a diluation factor of 20.

Notes:
All results in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

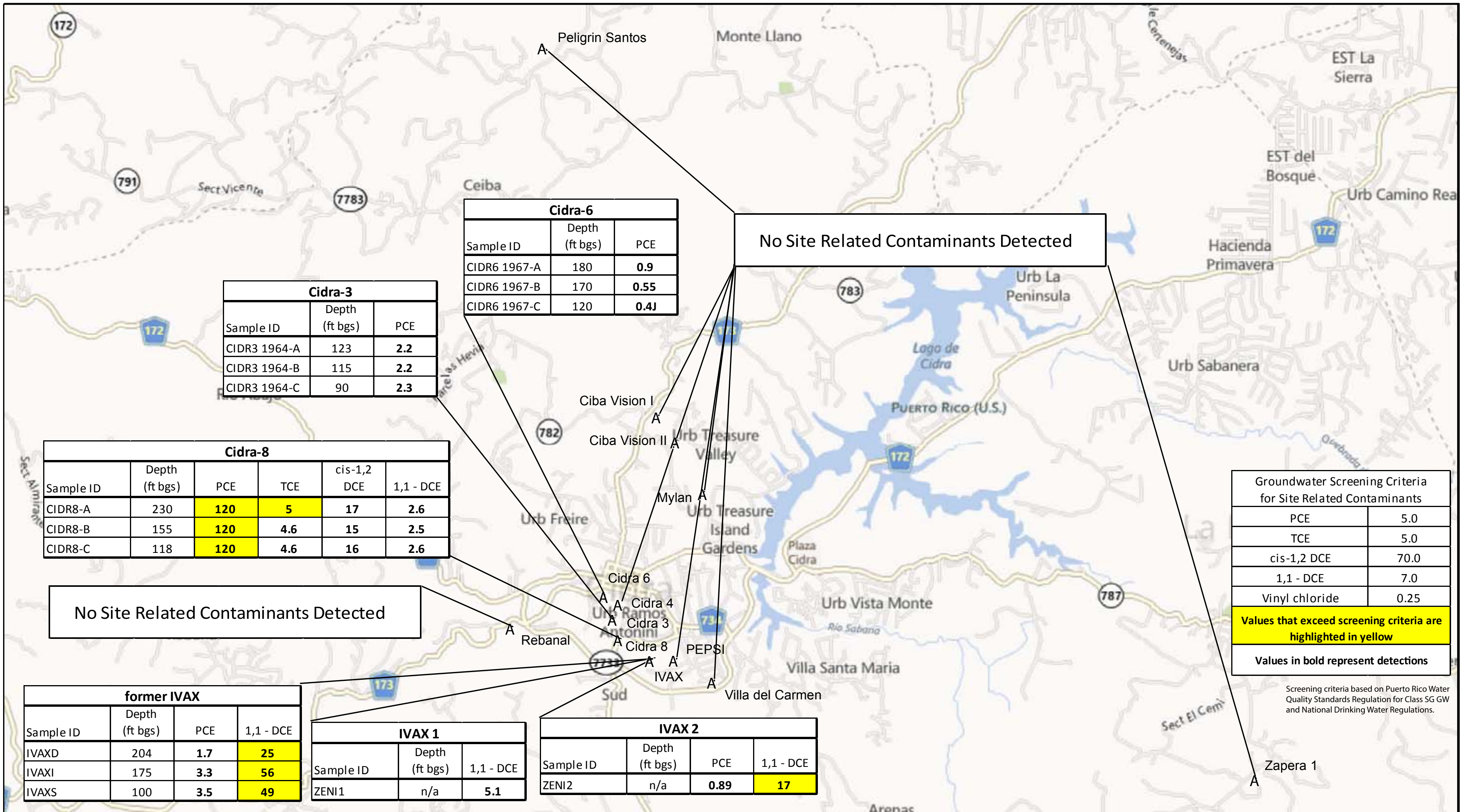
N

Feet
0 2 4 8 12 16

Figure 1-10
Site-Related Contaminant Soil Results - Don Quixote Pizza
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008966



Cidra-6

Sample ID	Depth (ft bgs)	PCE
CIDR6 1967-A	180	**0.9**
CIDR6 1967-B	170	**0.55**
CIDR6 1967-C	120	**0.4J**

Cidra-3

Sample ID	Depth (ft bgs)	PCE
CIDR3 1964-A	123	**2.2**
CIDR3 1964-B	115	**2.2**
CIDR3 1964-C	90	**2.3**

Cidra-8

Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE	1,1 - DCE
CIDR8-A	230	**120**	**5**	**17**	**2.6**
CIDR8-B	155	**120**	**4.6**	**15**	**2.5**
CIDR8-C	118	**120**	**4.6**	**16**	**2.6**

former IVAX

Sample ID	Depth (ft bgs)	PCE	1,1 - DCE
IVAXD	204	**1.7**	**25**
IVAXI	175	**3.3**	**56**
IVAXS	100	**3.5**	**49**

IVAX 1

Sample ID	Depth (ft bgs)	1,1 - DCE
ZENI1	n/a	**5.1**

IVAX 2

Sample ID	Depth (ft bgs)	PCE	1,1 - DCE
ZENI2	n/a	**0.89**	**17**

Groundwater Screening Criteria for Site Related Contaminants	
PCE	5.0
TCE	5.0
cis-1,2 DCE	70.0
1,1 - DCE	7.0
Vinyl chloride	0.25

Values that exceed screening criteria are highlighted in yellow

Values in bold represent detections

Screening criteria based on Puerto Rico Water Quality Standards Regulation for Class SG GW and National Drinking Water Regulations.

Notes:
All results in micrograms per liter (µg/L)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

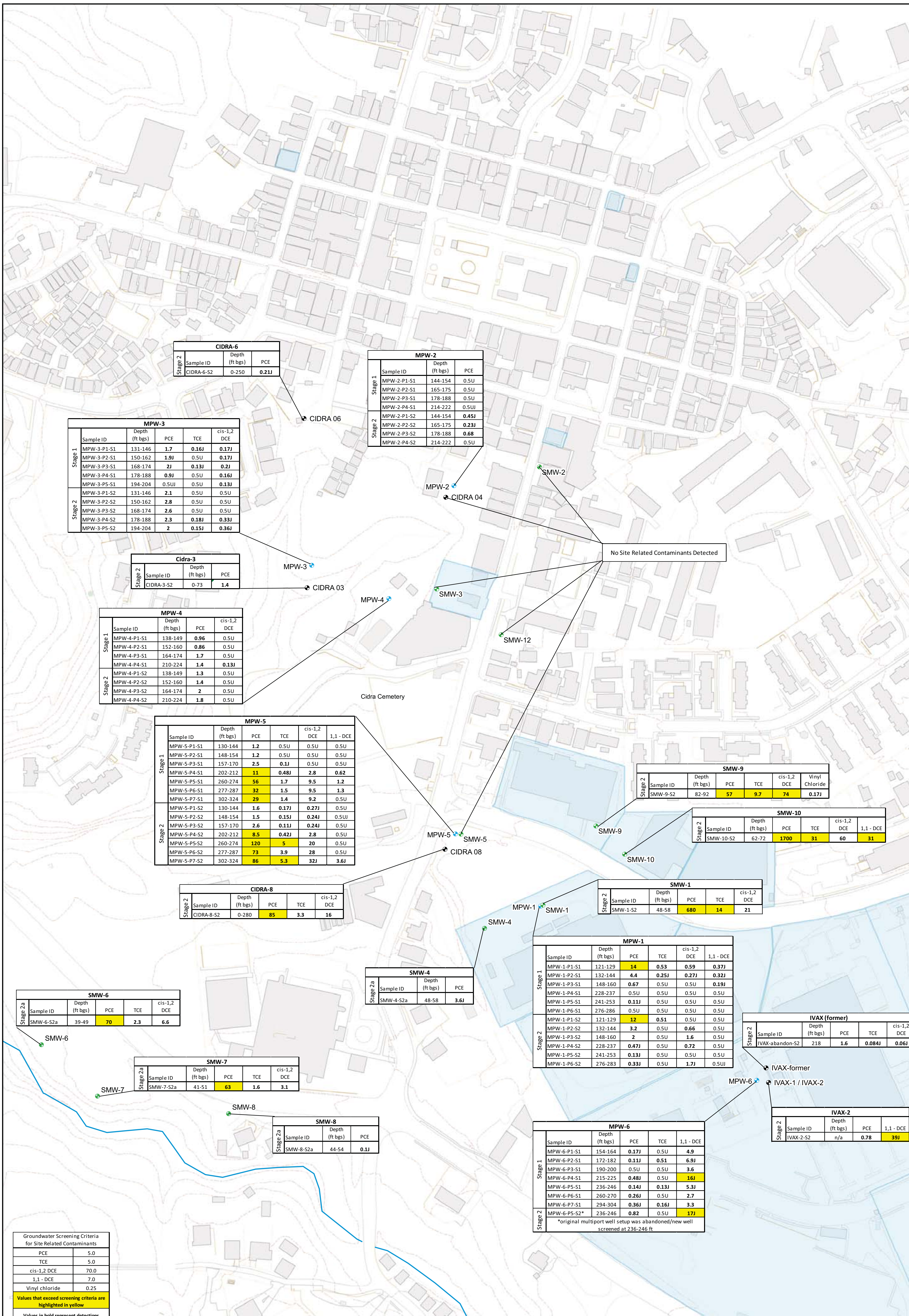
PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

N
0 0.25 0.5 1 Miles

Figure 1-11
Site-Related Contaminant Groundwater Results- Supply Wells (Initial Round)
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008967



CIDRA-6			
	Sample ID	Depth (ft bgs)	PCE
Stage 2	CIDRA-6-S2	0-250	**0.21J**

MPW-2			
	Sample ID	Depth (ft bgs)	PCE
Stage 1	MPW-2-P1-S1	144-154	0.5U
	MPW-2-P2-S1	165-175	0.5U
	MPW-2-P3-S1	178-188	0.5U
	MPW-2-P4-S1	214-222	0.5UJ
Stage 2	MPW-2-P1-S2	144-154	**0.45J**
	MPW-2-P2-S2	165-175	**0.23J**
	MPW-2-P3-S2	178-188	**0.68**
	MPW-2-P4-S2	214-222	0.5U

MPW-3					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 1	MPW-3-P1-S1	131-146	**1.7**	**0.16J**	**0.17J**
	MPW-3-P2-S1	150-162	**1.9J**	0.5U	**0.17J**
	MPW-3-P3-S1	168-174	**2J**	**0.13J**	**0.2J**
	MPW-3-P4-S1	178-188	**0.9J**	0.5U	**0.16J**
	MPW-3-P5-S1	194-204	0.5UJ	0.5U	**0.13J**
Stage 2	MPW-3-P1-S2	131-146	**2.1**	0.5U	0.5U
	MPW-3-P2-S2	150-162	**2.8**	0.5U	0.5U
	MPW-3-P3-S2	168-174	**2.6**	0.5U	0.5U
	MPW-3-P4-S2	178-188	**2.3**	**0.18J**	**0.33J**
	MPW-3-P5-S2	194-204	**2**	**0.15J**	**0.36J**

Cidra-3			
	Sample ID	Depth (ft bgs)	PCE
Stage 2	CIDRA-3-S2	0-73	**1.4**

MPW-4				
	Sample ID	Depth (ft bgs)	PCE	cis-1,2 DCE
Stage 1	MPW-4-P1-S1	138-149	**0.96**	0.5U
	MPW-4-P2-S1	152-160	**0.86**	0.5U
	MPW-4-P3-S1	164-174	**1.7**	0.5U
	MPW-4-P4-S1	210-224	**1.4**	**0.13J**
Stage 2	MPW-4-P1-S2	138-149	**1.3**	0.5U
	MPW-4-P2-S2	152-160	**1.4**	0.5U
	MPW-4-P3-S2	164-174	**2**	0.5U
	MPW-4-P4-S2	210-224	**1.8**	0.5U

MPW-5						
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE	1,1 - DCE
Stage 1	MPW-5-P1-S1	130-144	**1.2**	0.5U	0.5U	0.5U
	MPW-5-P2-S1	148-154	**1.2**	0.5U	0.5U	0.5U
	MPW-5-P3-S1	157-170	**2.5**	**0.1J**	0.5U	0.5U
	MPW-5-P4-S1	202-212	**11**	**0.48J**	**2.8**	**0.62**
	MPW-5-P5-S1	260-274	**56**	**1.7**	**9.5**	**1.2**
	MPW-5-P6-S1	277-287	**32**	**1.5**	**9.5**	**1.3**
	MPW-5-P7-S1	302-324	**29**	**1.4**	**9.2**	0.5U
Stage 2	MPW-5-P1-S2	130-144	**1.6**	**0.17J**	**0.27J**	0.5U
	MPW-5-P2-S2	148-154	**1.5**	**0.15J**	**0.24J**	0.5UJ
	MPW-5-P3-S2	157-170	**2.6**	**0.11J**	**0.24J**	0.5U
	MPW-5-P4-S2	202-212	**8.5**	**0.42J**	**2.8**	0.5U
	MPW-5-P5-S2	260-274	**120**	**5**	**20**	0.5U
	MPW-5-P6-S2	277-287	**73**	**3.9**	**28**	0.5U
	MPW-5-P7-S2	302-324	**86**	**5.3**	**32J**	**3.6J**

CIDRA-8					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 2	CIDRA-8-S2	0-280	**85**	**3.3**	**16**

SMW-9						
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE	Vinyl Chloride
Stage 2	SMW-9-S2	82-92	**57**	**9.7**	**74**	**0.17J**

SMW-10						
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE	1,1 - DCE
Stage 2	SMW-10-S2	62-72	**1700**	**31**	**60**	**31**

SMW-1					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 2	SMW-1-S2	48-58	**680**	**14**	**21**

MPW-1						
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE	1,1 - DCE
Stage 1	MPW-1-P1-S1	121-129	**14**	**0.53**	**0.59**	**0.37J**
	MPW-1-P2-S1	132-144	**4.4**	**0.25J**	**0.27J**	**0.32J**
	MPW-1-P3-S1	148-160	**0.67**	0.5U	0.5U	**0.19J**
	MPW-1-P4-S1	228-237	0.5U	0.5U	0.5U	0.5U
	MPW-1-P5-S1	241-253	**0.11J**	0.5U	0.5U	0.5U
	MPW-1-P6-S1	276-286	0.5U	0.5U	0.5U	0.5U
Stage 2	MPW-1-P1-S2	121-129	**12**	**0.51**	0.5U	0.5U
	MPW-1-P2-S2	132-144	**3.2**	0.5U	**0.66**	0.5U
	MPW-1-P3-S2	148-160	**2**	0.5U	**1.6**	0.5U
	MPW-1-P4-S2	228-237	**0.47J**	0.5U	**0.72**	0.5U
	MPW-1-P5-S2	241-253	**0.13J**	0.5U	0.5U	0.5U
	MPW-1-P6-S2	276-283	**0.33J**	0.5U	**1.7J**	0.5UJ

SMW-4			
	Sample ID	Depth (ft bgs)	PCE
Stage 2a	SMW-4-S2a	48-58	**3.6J**

IVAX (former)					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 2	IVAX-abandon-S2	218	**1.6**	**0.084J**	**0.06J**

SMW-6					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 2a	SMW-6-S2a	39-49	**70**	**2.3**	**6.6**

SMW-7					
	Sample ID	Depth (ft bgs)	PCE	TCE	cis-1,2 DCE
Stage 2a	SMW-7-S2a	41-51	**63**	**1.6**	**3.1**

SMW-8			
	Sample ID	Depth (ft bgs)	PCE
Stage 2a	SMW-8-S2a	44-54	**0.1J**

IVAX-2				
	Sample ID	Depth (ft bgs)	PCE	1,1 - DCE
Stage 2	IVAX-2-S2	n/a	**0.78**	**39J**

MPW-6				
	Sample ID	Depth (ft bgs)	PCE	TCE	1,1 - DCE
Stage 1	MPW-6-P1-S1	154-164	**0.17J**	0.5U	**4.9**
	MPW-6-P2-S1	172-182	**0.11J**	**0.51**	**6.9J**
	MPW-6-P3-S1	190-200	0.5U	0.5U	**3.6**
	MPW-6-P4-S1	215-225	**0.48J**	0.5U	**16J**
	MPW-6-P5-S1	236-246	**0.14J**	**0.13J**	**5.3J**
	MPW-6-P6-S1	260-270	**0.26J**	0.5U	**2.7**
	MPW-6-P7-S1	294-304	**0.36J**	**0.16J**	**3.3**
Stage 2	MPW-6-P5-S2*	236-246	**0.82**	0.5U	**17J**
	*original multiport well setup was abandoned/new well screened at 236-246 ft				

Groundwater Screening Criteria for Site Related Contaminants	
PCE	5.0
TCE	5.0
cis-1,2 DCE	70.0
1,1 - DCE	7.0
Vinyl chloride	0.25
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

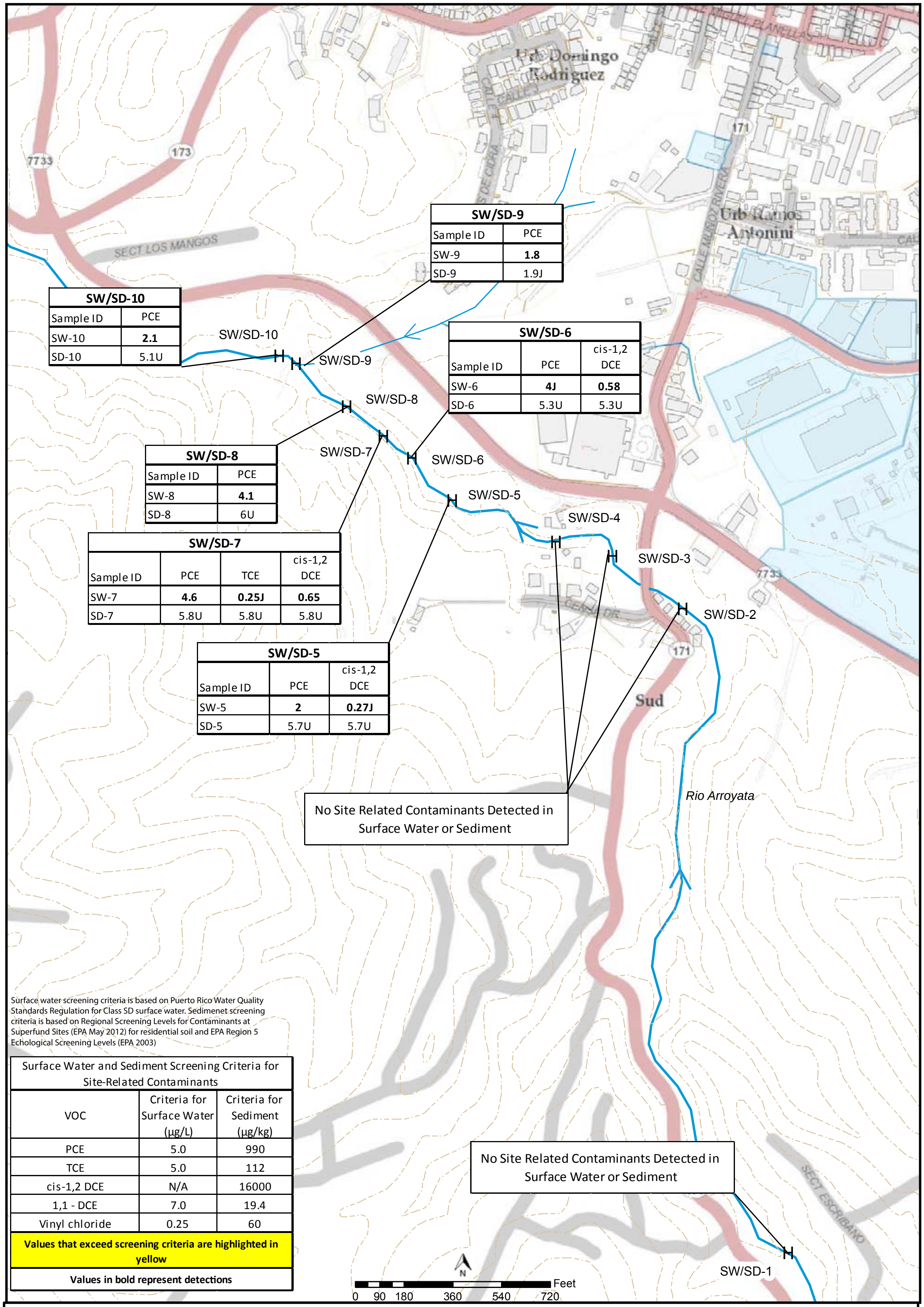
Notes:
All results in micrograms per liter (µg/L)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit
PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

0 50 100 200 300 400 Feet

Figure 1-12
Site-Related Contaminant Groundwater Results - Stage 1, Stage 2 and Stage 2a
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008968



SW/SD-10

Sample ID	PCE
SW-10	**2.1**
SD-10	5.1U

SW/SD-9

Sample ID	PCE
SW-9	**1.8**
SD-9	1.9J

SW/SD-8

Sample ID	PCE
SW-8	**4.1**
SD-8	6U

SW/SD-7

Sample ID	PCE	TCE	cis-1,2 DCE
SW-7	**4.6**	**0.25J**	**0.65**
SD-7	5.8U	5.8U	5.8U

SW/SD-6

Sample ID	PCE	cis-1,2 DCE
SW-6	**4J**	**0.58**
SD-6	5.3U	5.3U

SW/SD-5

Sample ID	PCE	cis-1,2 DCE
SW-5	**2**	**0.27J**
SD-5	5.7U	5.7U

Surface water screening criteria is based on Puerto Rico Water Quality Standards Regulation for Class SD surface water. Sedimenet screening criteria is based on Regional Screening Levels for Contaminants at Superfund Sites (EPA May 2012) for residential soil and EPA Region 5 Echological Screening Levels (EPA 2003)

Surface Water and Sediment Screening Criteria for Site-Related Contaminants

VOC	Criteria for Surface Water (µg/L)	Criteria for Sediment (µg/kg)
PCE	5.0	990
TCE	5.0	112
cis-1,2 DCE	N/A	16000
1,1 - DCE	7.0	19.4
Vinyl chloride	0.25	60

Values that exceed screening criteria are highlighted in yellow

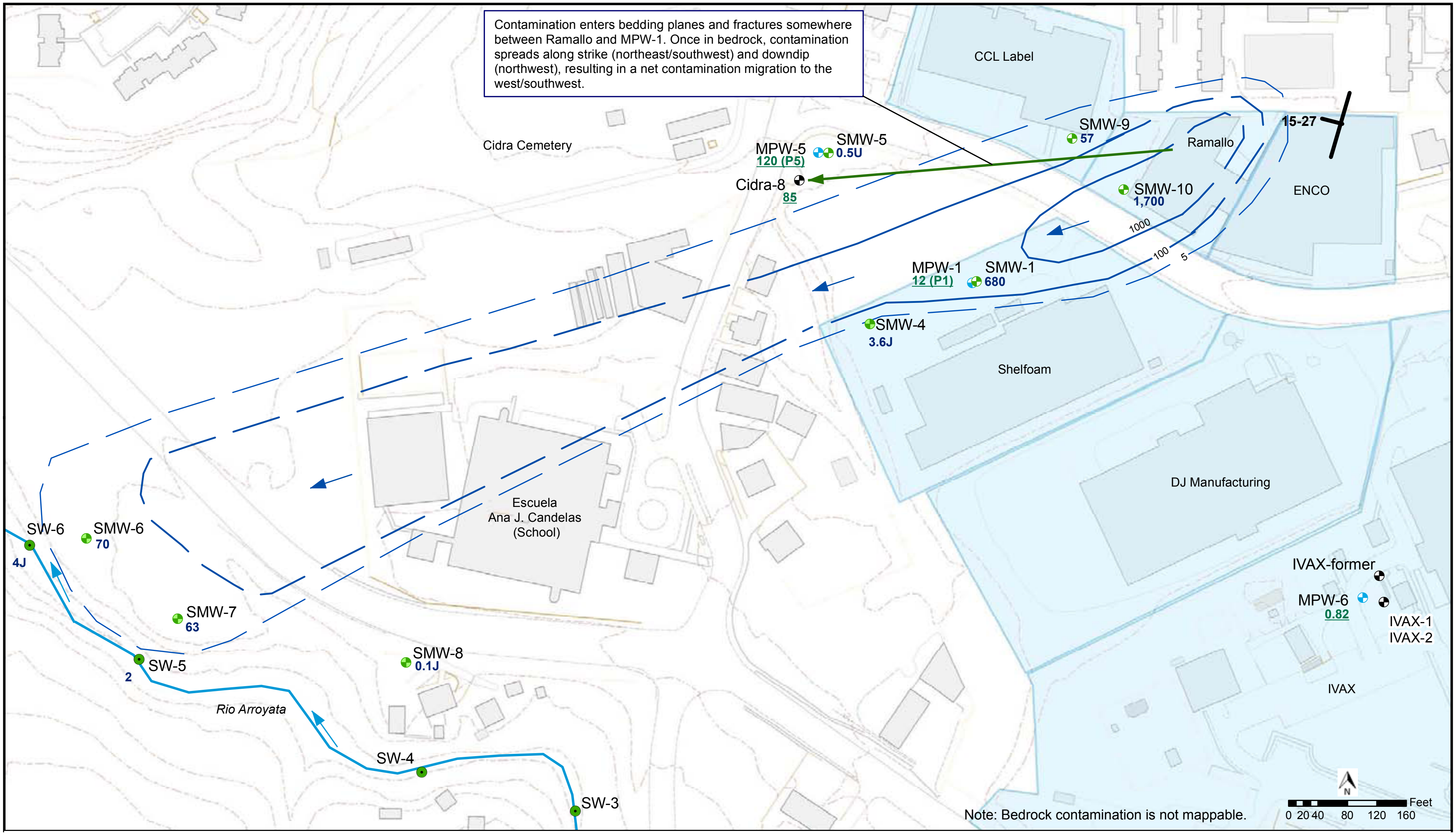
Values in bold represent detections

Notes:
All sediment results in micrograms per liter (µg/L)
All surface water results in micrograms per kilogram (µg/kg)
U - not detected above the listed detection limit
VOC - volatile organic compound
PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene
J- estimated value

Figure 1-13
Site-Related Contaminant Surface Water and Sediment Results
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008969



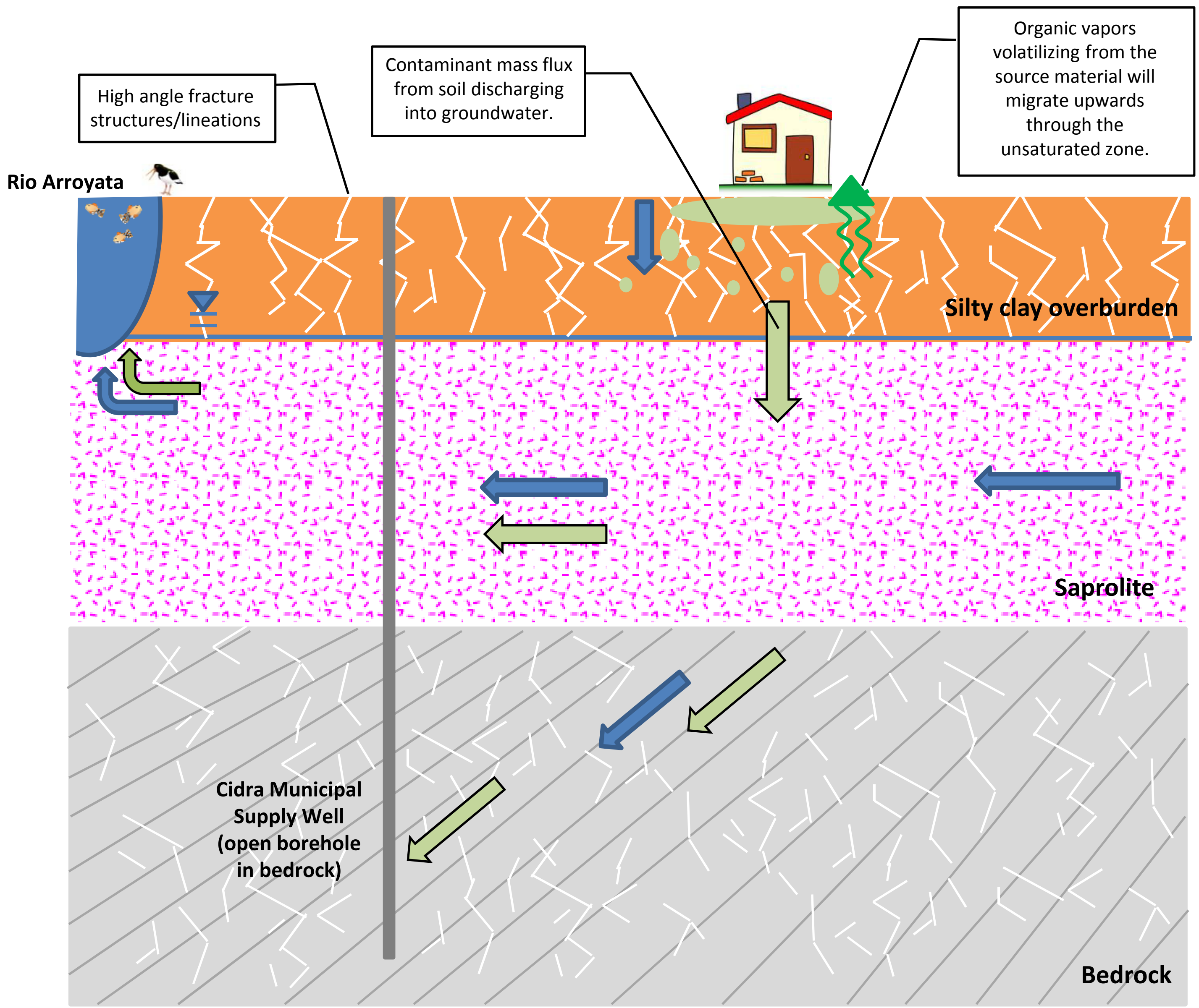
Legend

- Cidra Public Supply Well Location (out of service)
- Industrial Supply Well
- MPW - Multiport Well Location (Installed during Stage 1)
- SMW- Saprolite Monitoring Well Location (Installed during Stage 2)
- SMW - Saprolite Monitoring Well Location (Installed during Stage 2a)
- SW - Surface Water Sample Location (Collected during Stage 2a)
- Contaminant Movement in Saprolite
- Net Contaminant Movement in Bedrock
- 1,700 PCE Level in Saprolite Well
- 1,700 PCE Level in Bedrock Well (highest level & port #)
- PCE Contour in Saprolite
- Topographic contour line (10 foot interval)

Figure 1-14
PCE Plume in Saprolite
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

R2-0008970



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Note: Not to scale.

Figure 1-15
Conceptual Site Model
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

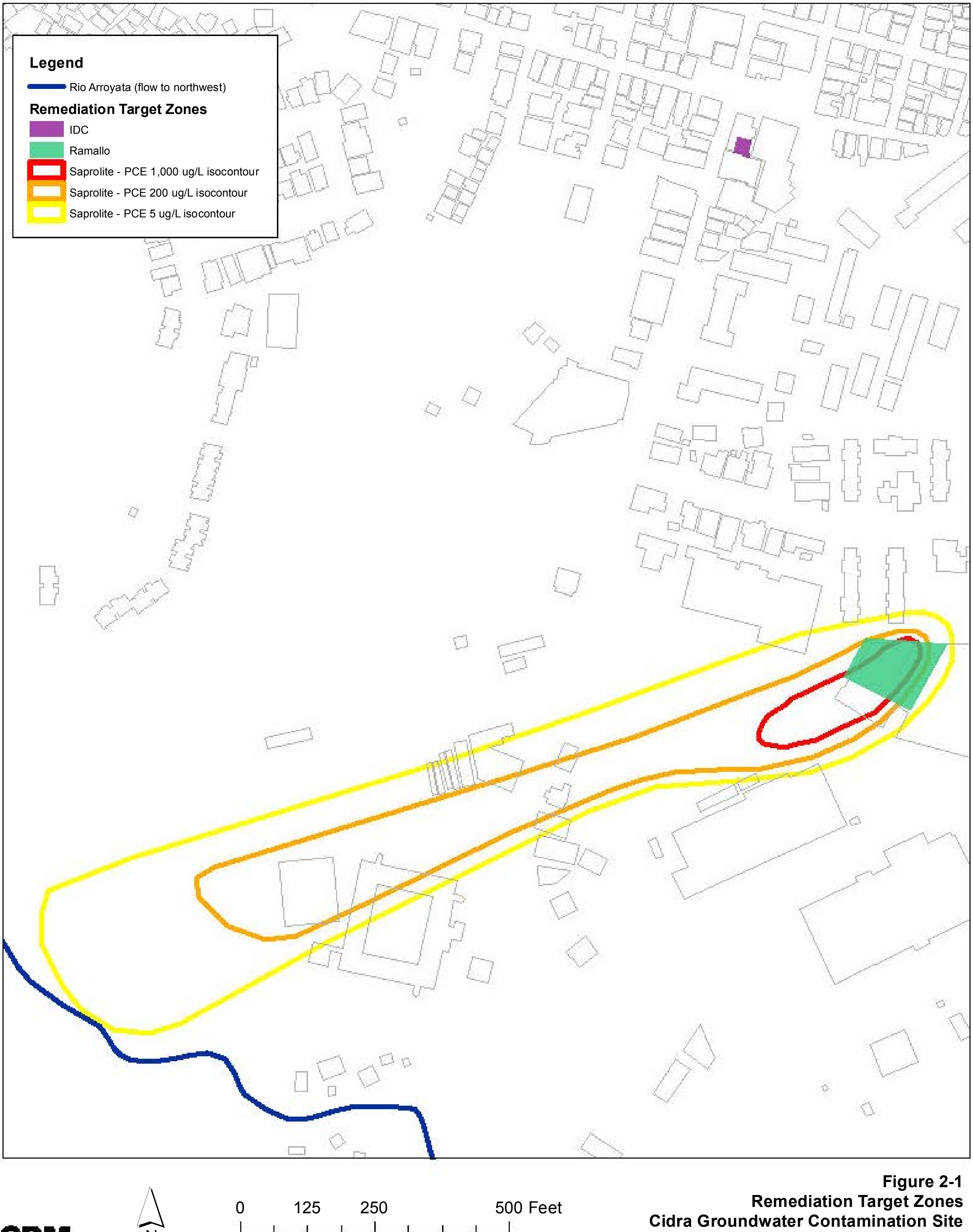

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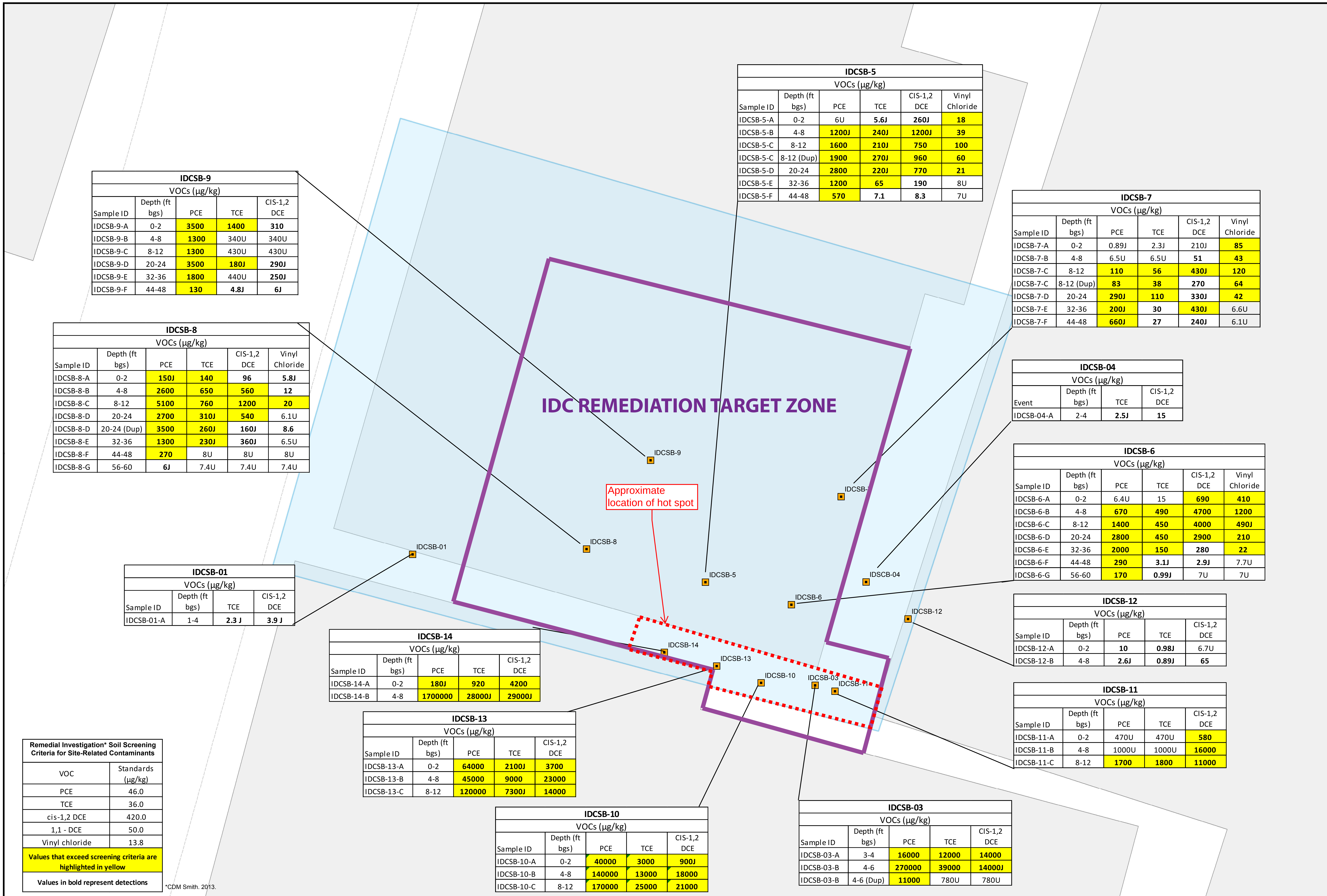
Figure 2-1
Remediation Target Zones
Cidra Groundwater Contamination Site
Cidra, Puerto Rico



IDCSB-9				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-9-A	0-2	3500	1400	310
IDCSB-9-B	4-8	1300	340U	340U
IDCSB-9-C	8-12	1300	430U	430U
IDCSB-9-D	20-24	3500	180J	290J
IDCSB-9-E	32-36	1800	440U	250J
IDCSB-9-F	44-48	130	4.8J	6J

IDCSB-5					
VOCs (µg/kg)					
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-5-A	0-2	6U	5.6J	260J	18
IDCSB-5-B	4-8	1200J	240J	1200J	39
IDCSB-5-C	8-12	1600	210J	750	100
IDCSB-5-C	8-12 (Dup)	1900	270J	960	60
IDCSB-5-D	20-24	2800	220J	770	21
IDCSB-5-E	32-36	1200	65	190	8U
IDCSB-5-F	44-48	570	7.1	8.3	7U

IDCSB-7					
VOCs (µg/kg)					
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-7-A	0-2	0.89J	2.3J	210J	85
IDCSB-7-B	4-8	6.5U	6.5U	51	43
IDCSB-7-C	8-12	110	56	430J	120
IDCSB-7-C	8-12 (Dup)	83	38	270	64
IDCSB-7-D	20-24	290J	110	330J	42
IDCSB-7-E	32-36	200J	30	430J	6.6U
IDCSB-7-F	44-48	660J	27	240J	6.1U

IDCSB-8					
VOCs (µg/kg)					
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-8-A	0-2	150J	140	96	5.8J
IDCSB-8-B	4-8	2600	650	560	12
IDCSB-8-C	8-12	5100	760	1200	20
IDCSB-8-D	20-24	2700	310J	540	6.1U
IDCSB-8-D	20-24 (Dup)	3500	260J	160J	8.6
IDCSB-8-E	32-36	1300	230J	360J	6.5U
IDCSB-8-F	44-48	270	8U	8U	8U
IDCSB-8-G	56-60	6J	7.4U	7.4U	7.4U

IDCSB-04			
VOCs (µg/kg)			
Event	Depth (ft bgs)	TCE	CIS-1,2 DCE
IDCSB-04-A	2-4	2.5J	15

IDCSB-6					
VOCs (µg/kg)					
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
IDCSB-6-A	0-2	6.4U	15	690	410
IDCSB-6-B	4-8	670	490	4700	1200
IDCSB-6-C	8-12	1400	450	4000	490J
IDCSB-6-D	20-24	2800	450	2900	210
IDCSB-6-E	32-36	2000	150	280	22
IDCSB-6-F	44-48	290	3.1J	2.9J	7.7U
IDCSB-6-G	56-60	170	0.99J	7U	7U

IDCSB-01			
VOCs (µg/kg)			
Sample ID	Depth (ft bgs)	TCE	CIS-1,2 DCE
IDCSB-01-A	1-4	2.3 J	3.9 J

IDCSB-12				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-12-A	0-2	10	0.98J	6.7U
IDCSB-12-B	4-8	2.6J	0.89J	65

IDCSB-14				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-14-A	0-2	180J	920	4200
IDCSB-14-B	4-8	1700000	28000J	29000J

IDCSB-11				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-11-A	0-2	470U	470U	580
IDCSB-11-B	4-8	1000U	1000U	16000
IDCSB-11-C	8-12	1700	1800	11000

IDCSB-13				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-13-A	0-2	64000	2100J	3700
IDCSB-13-B	4-8	45000	9000	23000
IDCSB-13-C	8-12	120000	7300J	14000

Remedial Investigation* Soil Screening Criteria for Site-Related Contaminants	
VOC	Standards (µg/kg)
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

*CDM Smith. 2013.

IDCSB-10				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-10-A	0-2	40000	3000	900J
IDCSB-10-B	4-8	140000	13000	18000
IDCSB-10-C	8-12	170000	25000	21000

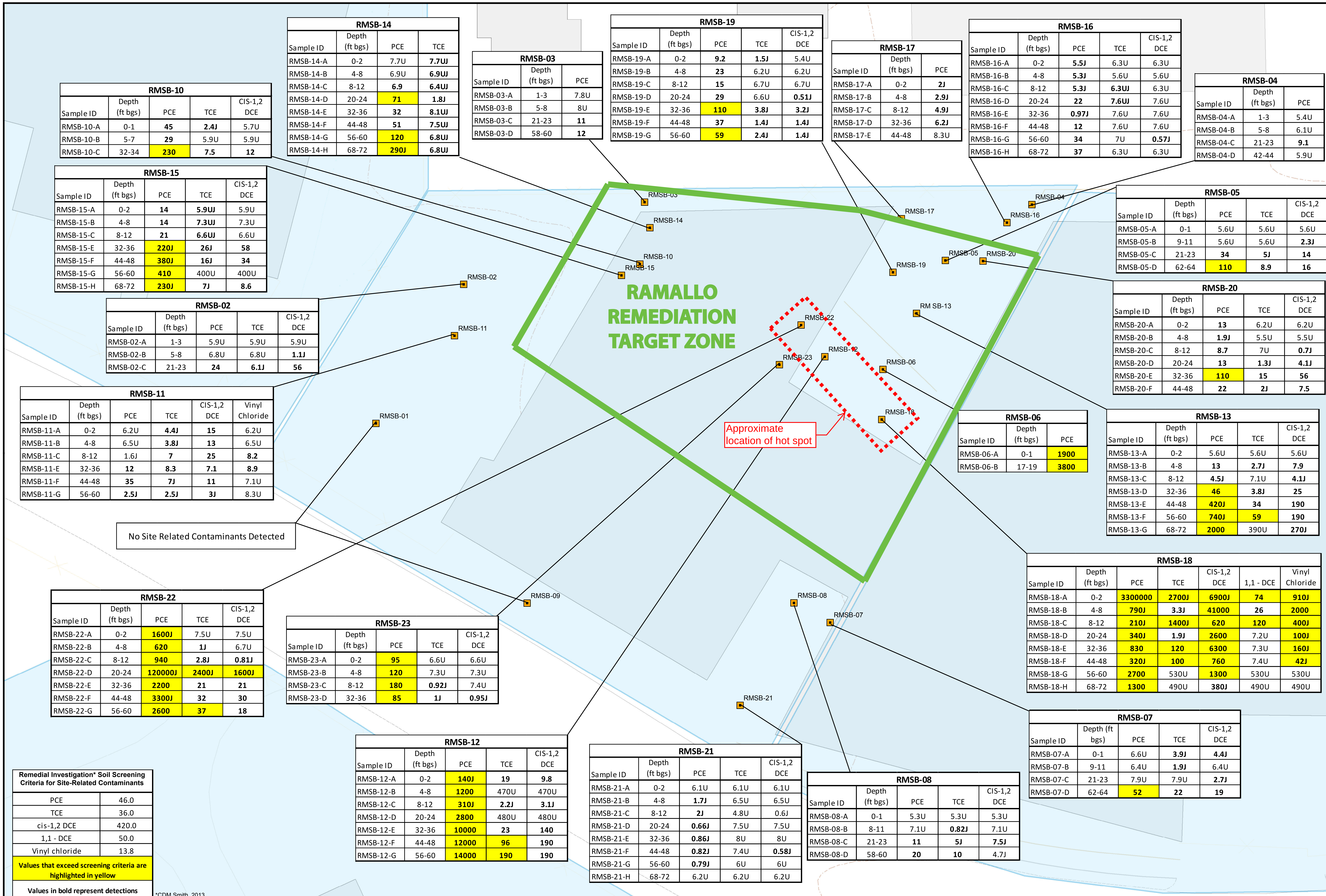
IDCSB-03				
VOCs (µg/kg)				
Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
IDCSB-03-A	3-4	16000	12000	14000
IDCSB-03-B	4-6	270000	39000	14000J
IDCSB-03-B	4-6 (Dup)	11000	780U	780U

Notes:
Detections are in bold
ft bgs - feet below ground surface
J - estimated value
µg/kg - micrograms per kilograms
U - not detected above the listed detection limit

VOC - volatile organic compound
PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene
SRC - Site Related Contaminants

Figure 2-2
IDC Remediation Target Zone
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith



RMSB-14

Sample ID	Depth (ft bgs)	PCE	TCE
RMSB-14-A	0-2	7.7U	7.7UJ
RMSB-14-B	4-8	6.9U	6.9UJ
RMSB-14-C	8-12	6.9	6.4UJ
RMSB-14-D	20-24	71	1.8J
RMSB-14-E	32-36	32	8.1UJ
RMSB-14-F	44-48	51	7.5UJ
RMSB-14-G	56-60	120	6.8UJ
RMSB-14-H	68-72	290J	6.8UJ

RMSB-03

Sample ID	Depth (ft bgs)	PCE
RMSB-03-A	1-3	7.8U
RMSB-03-B	5-8	8U
RMSB-03-C	21-23	11
RMSB-03-D	58-60	12

RMSB-19

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-19-A	0-2	9.2	1.5J	5.4U
RMSB-19-B	4-8	23	6.2U	6.2U
RMSB-19-C	8-12	15	6.7U	6.7U
RMSB-19-D	20-24	29	6.6U	0.51J
RMSB-19-E	32-36	110	3.8J	3.2J
RMSB-19-F	44-48	37	1.4J	1.4J
RMSB-19-G	56-60	59	2.4J	1.4J

RMSB-17

Sample ID	Depth (ft bgs)	PCE
RMSB-17-A	0-2	2J
RMSB-17-B	4-8	2.9J
RMSB-17-C	8-12	4.9J
RMSB-17-D	32-36	6.2J
RMSB-17-E	44-48	8.3U

RMSB-16

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-16-A	0-2	5.5J	6.3U	6.3U
RMSB-16-B	4-8	5.3J	5.6U	5.6U
RMSB-16-C	8-12	5.3J	6.3UJ	6.3U
RMSB-16-D	20-24	22	7.6UJ	7.6U
RMSB-16-E	32-36	0.97J	7.6U	7.6U
RMSB-16-F	44-48	12	7.6U	7.6U
RMSB-16-G	56-60	34	7U	0.57J
RMSB-16-H	68-72	37	6.3U	6.3U

RMSB-04

Sample ID	Depth (ft bgs)	PCE
RMSB-04-A	1-3	5.4U
RMSB-04-B	5-8	6.1U
RMSB-04-C	21-23	9.1
RMSB-04-D	42-44	5.9U

RMSB-10

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-10-A	0-1	45	2.4J	5.7U
RMSB-10-B	5-7	29	5.9U	5.9U
RMSB-10-C	32-34	230	7.5	12

RMSB-15

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-15-A	0-2	14	5.9UJ	5.9U
RMSB-15-B	4-8	14	7.3UJ	7.3U
RMSB-15-C	8-12	21	6.6UJ	6.6U
RMSB-15-E	32-36	220J	26J	58
RMSB-15-F	44-48	380J	16J	34
RMSB-15-G	56-60	410	400U	400U
RMSB-15-H	68-72	230J	7J	8.6

RMSB-05

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-05-A	0-1	5.6U	5.6U	5.6U
RMSB-05-B	9-11	5.6U	5.6U	2.3J
RMSB-05-C	21-23	34	5J	14
RMSB-05-D	62-64	110	8.9	16

RMSB-02

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-02-A	1-3	5.9U	5.9U	5.9U
RMSB-02-B	5-8	6.8U	6.8U	1.1J
RMSB-02-C	21-23	24	6.1J	56

RMSB-20

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-20-A	0-2	13	6.2U	6.2U
RMSB-20-B	4-8	1.9J	5.5U	5.5U
RMSB-20-C	8-12	8.7	7U	0.7J
RMSB-20-D	20-24	13	1.3J	4.1J
RMSB-20-E	32-36	110	15	56
RMSB-20-F	44-48	22	2J	7.5

RMSB-11

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	Vinyl Chloride
RMSB-11-A	0-2	6.2U	4.4J	15	6.2U
RMSB-11-B	4-8	6.5U	3.8J	13	6.5U
RMSB-11-C	8-12	1.6J	7	25	8.2
RMSB-11-E	32-36	12	8.3	7.1	8.9
RMSB-11-F	44-48	35	7J	11	7.1U
RMSB-11-G	56-60	2.5J	2.5J	3J	8.3U

RMSB-06

Sample ID	Depth (ft bgs)	PCE
RMSB-06-A	0-1	1900
RMSB-06-B	17-19	3800

RMSB-13

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-13-A	0-2	5.6U	5.6U	5.6U
RMSB-13-B	4-8	13	2.7J	7.9
RMSB-13-C	8-12	4.5J	7.1U	4.1J
RMSB-13-D	32-36	46	3.8J	25
RMSB-13-E	44-48	420J	34	190
RMSB-13-F	56-60	740J	59	190
RMSB-13-G	68-72	2000	390U	270J

RMSB-18

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE	1,1 - DCE	Vinyl Chloride
RMSB-18-A	0-2	3300000	2700J	6900J	74	910J
RMSB-18-B	4-8	790J	3.3J	41000	26	2000
RMSB-18-C	8-12	210J	1400J	620	120	400J
RMSB-18-D	20-24	340J	1.9J	2600	7.2U	100J
RMSB-18-E	32-36	830	120	6300	7.3U	160J
RMSB-18-F	44-48	320J	100	760	7.4U	42J
RMSB-18-G	56-60	2700	530U	1300	530U	530U
RMSB-18-H	68-72	1300	490U	380J	490U	490U

RMSB-22

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-22-A	0-2	1600J	7.5U	7.5U
RMSB-22-B	4-8	620	1J	6.7U
RMSB-22-C	8-12	940	2.8J	0.81J
RMSB-22-D	20-24	120000J	2400J	1600J
RMSB-22-E	32-36	2200	21	21
RMSB-22-F	44-48	3300J	32	30
RMSB-22-G	56-60	2600	37	18

RMSB-23

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-23-A	0-2	95	6.6U	6.6U
RMSB-23-B	4-8	120	7.3U	7.3U
RMSB-23-C	8-12	180	0.92J	7.4U
RMSB-23-D	32-36	85	1J	0.95J

RMSB-12

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-12-A	0-2	140J	19	9.8
RMSB-12-B	4-8	1200	470U	470U
RMSB-12-C	8-12	310J	2.2J	3.1J
RMSB-12-D	20-24	2800	480U	480U
RMSB-12-E	32-36	10000	23	140
RMSB-12-F	44-48	12000	96	190
RMSB-12-G	56-60	14000	190	190

RMSB-21

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-21-A	0-2	6.1U	6.1U	6.1U
RMSB-21-B	4-8	1.7J	6.5U	6.5U
RMSB-21-C	8-12	2J	4.8U	0.6J
RMSB-21-D	20-24	0.66J	7.5U	7.5U
RMSB-21-E	32-36	0.86J	8U	8U
RMSB-21-F	44-48	0.82J	7.4U	0.58J
RMSB-21-G	56-60	0.79J	6U	6U
RMSB-21-H	68-72	6.2U	6.2U	6.2U

RMSB-08

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-08-A	0-1	5.3U	5.3U	5.3U
RMSB-08-B	8-11	7.1U	0.82J	7.1U
RMSB-08-C	21-23	11	5J	7.5J
RMSB-08-D	58-60	20	10	4.7J

RMSB-07

Sample ID	Depth (ft bgs)	PCE	TCE	CIS-1,2 DCE
RMSB-07-A	0-1	6.6U	3.9J	4.4J
RMSB-07-B	9-11	6.4U	1.9J	6.4U
RMSB-07-C	21-23	7.9U	7.9U	2.7J
RMSB-07-D	62-64	52	22	19

Remedial Investigation* Soil Screening Criteria for Site-Related Contaminants	
PCE	46.0
TCE	36.0
cis-1,2 DCE	420.0
1,1 - DCE	50.0
Vinyl chloride	13.8
Values that exceed screening criteria are highlighted in yellow	
Values in bold represent detections	

*CDM Smith. 2013.

Notes:
All results in micrograms per kilogram (µg/kg)
ft bgs - feet below ground surface
J - estimated value
U - not detected above the listed detection limit

PCE - tetrachloroethene
TCE - trichloroethene
DCE - dichloroethene

Figure 2-3
Ramallo Remediation Target Zone
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

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R2-0008974

Figure 4-1
Alternative IDC-S2 – Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

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R2-0008975

Figure 4-2
Alternative IDC-S3 – SVE and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

R2-0008976

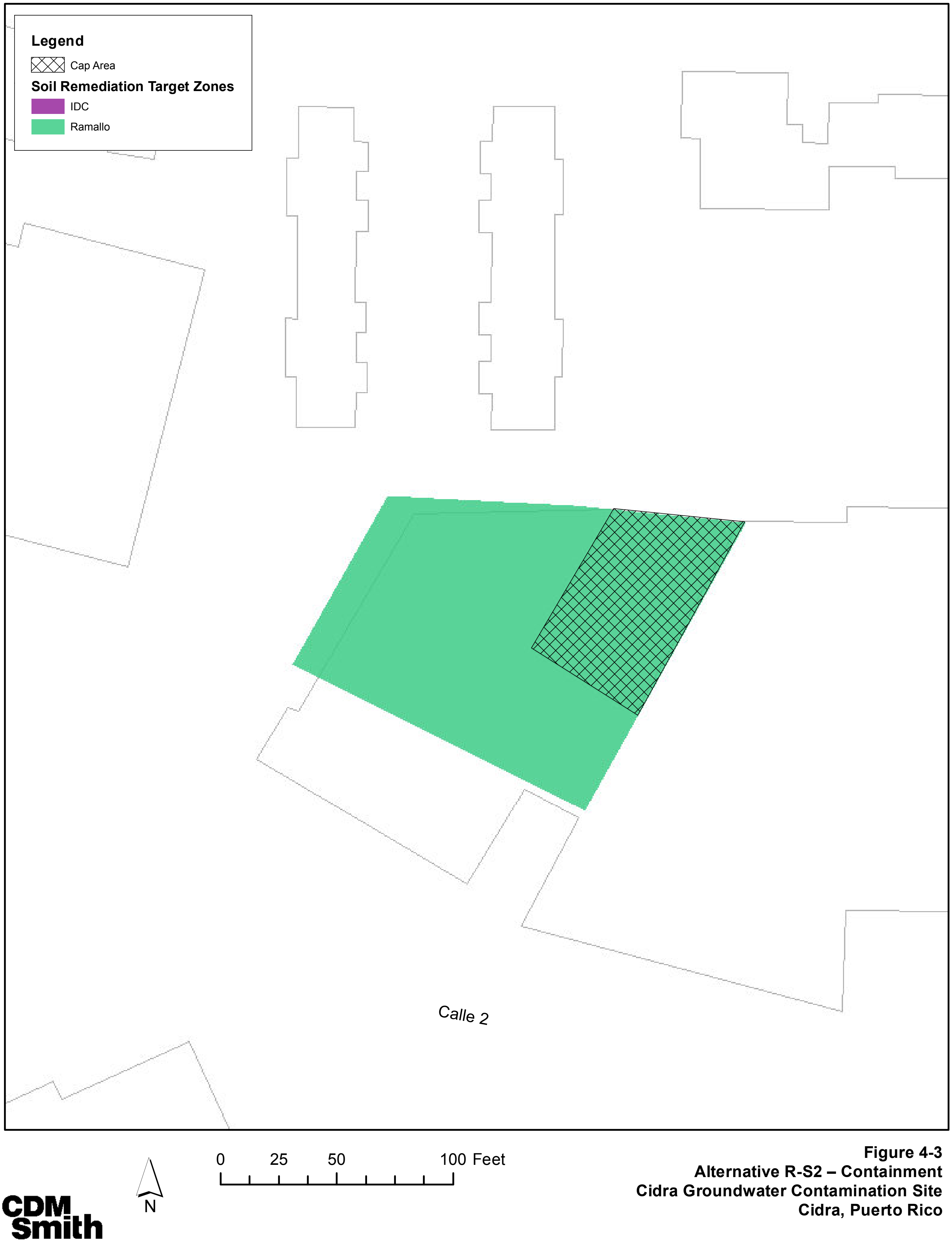


Figure 4-3
Alternative R-S2 – Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

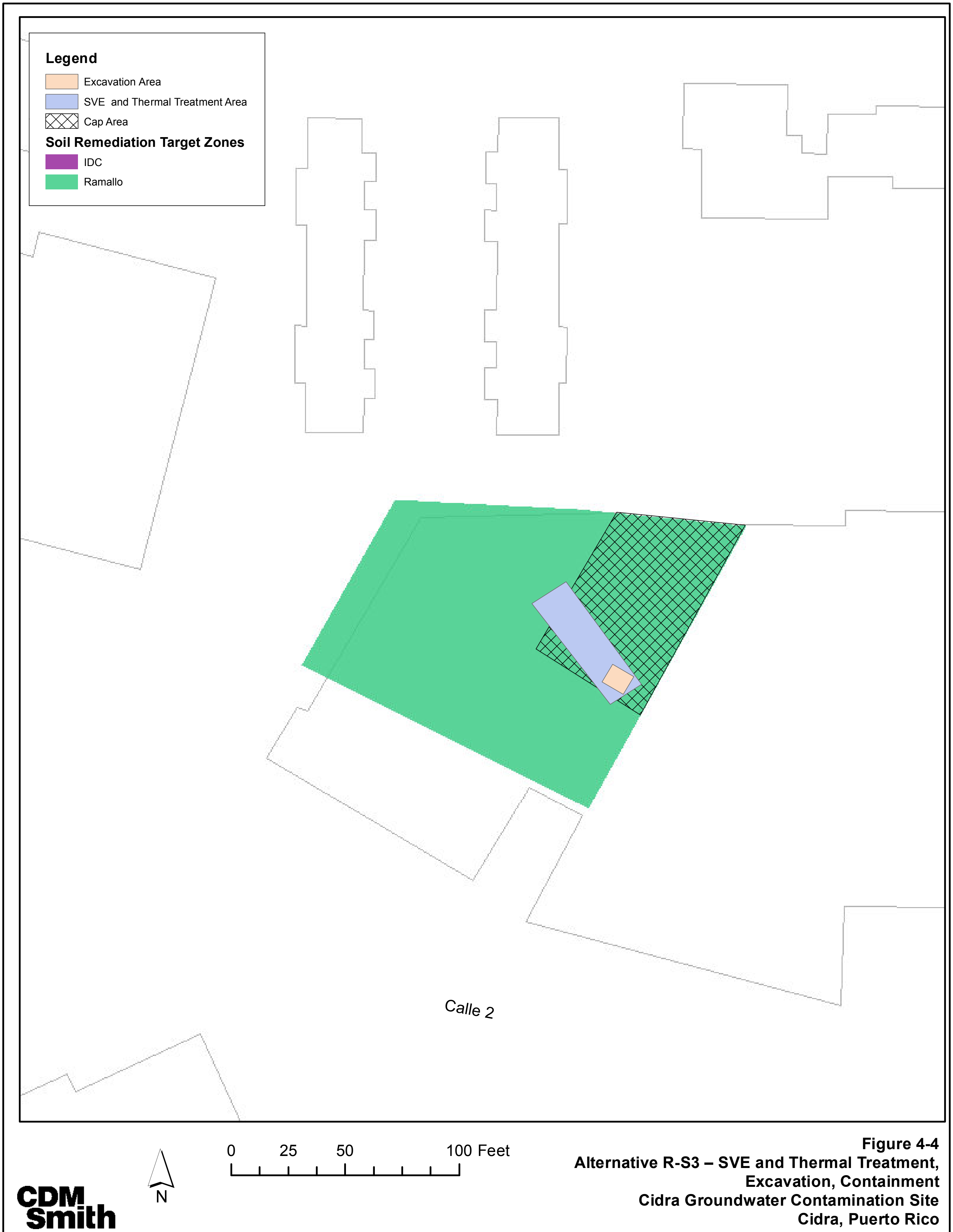


Figure 4-4
Alternative R-S3 – SVE and Thermal Treatment, Excavation, Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

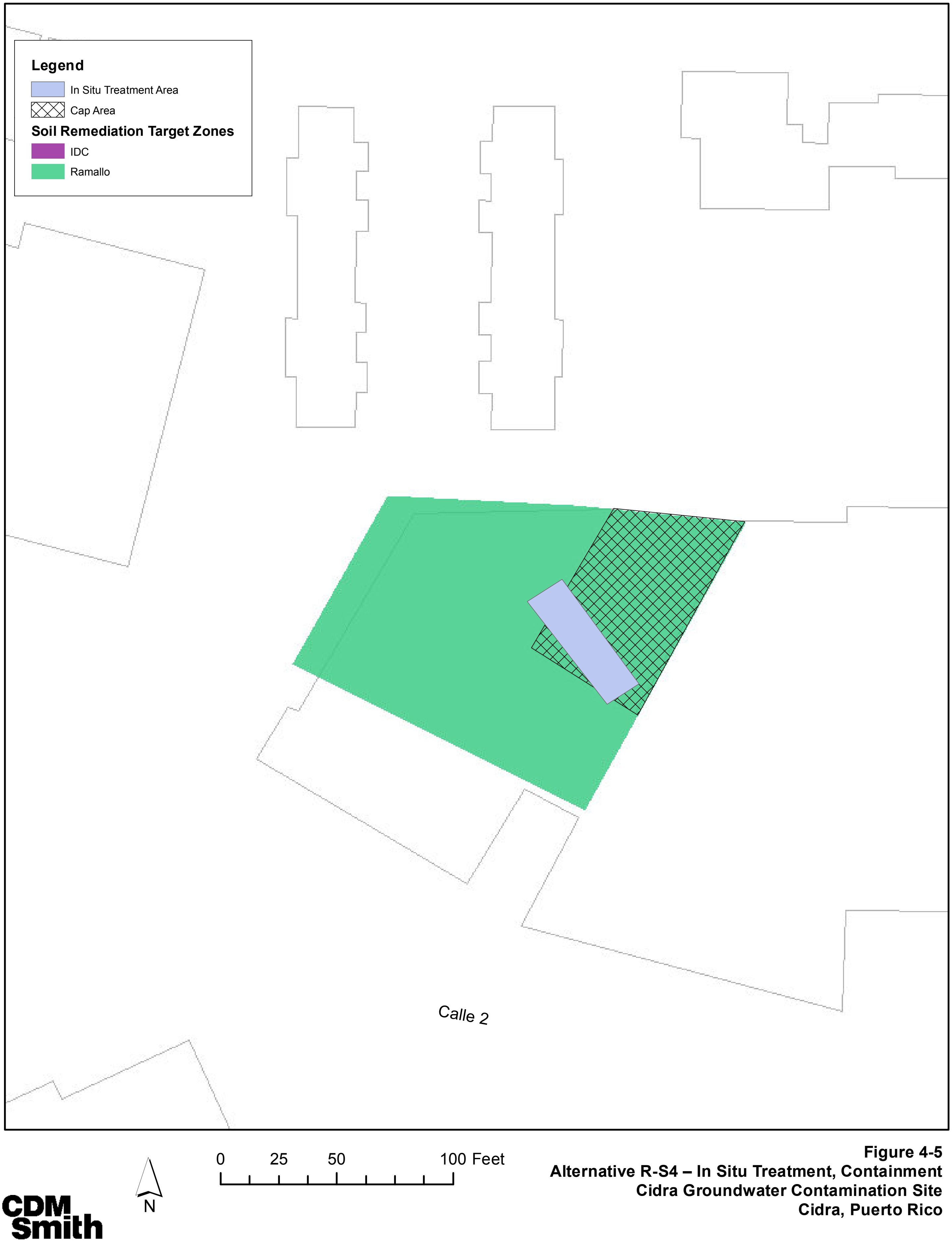
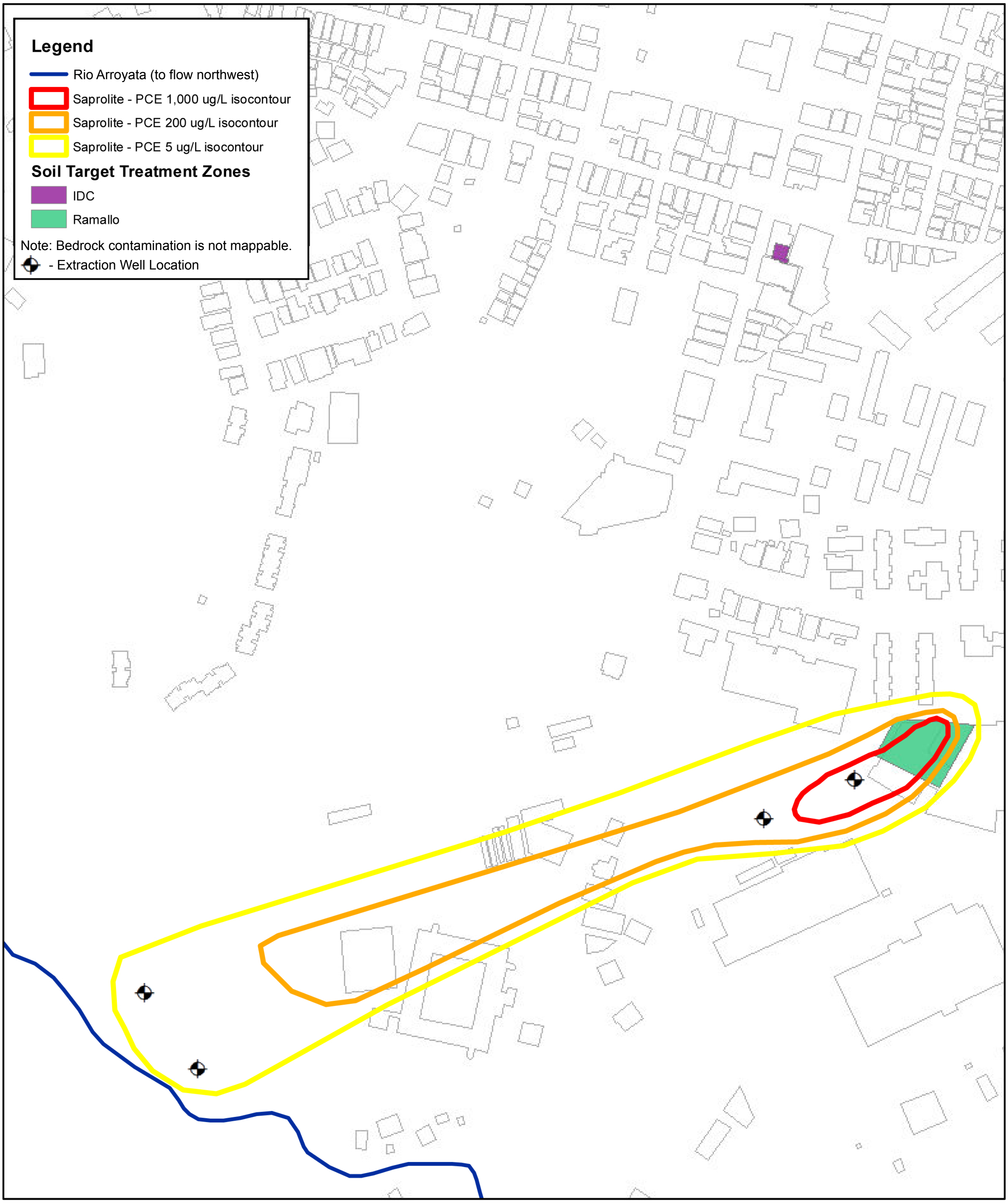


Figure 4-5
Alternative R-S4 – In Situ Treatment, Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico



N

0 160 320 640 Feet

Figure 4-6
Alternative GW2 Extraction Well Locations
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

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R2-0008980

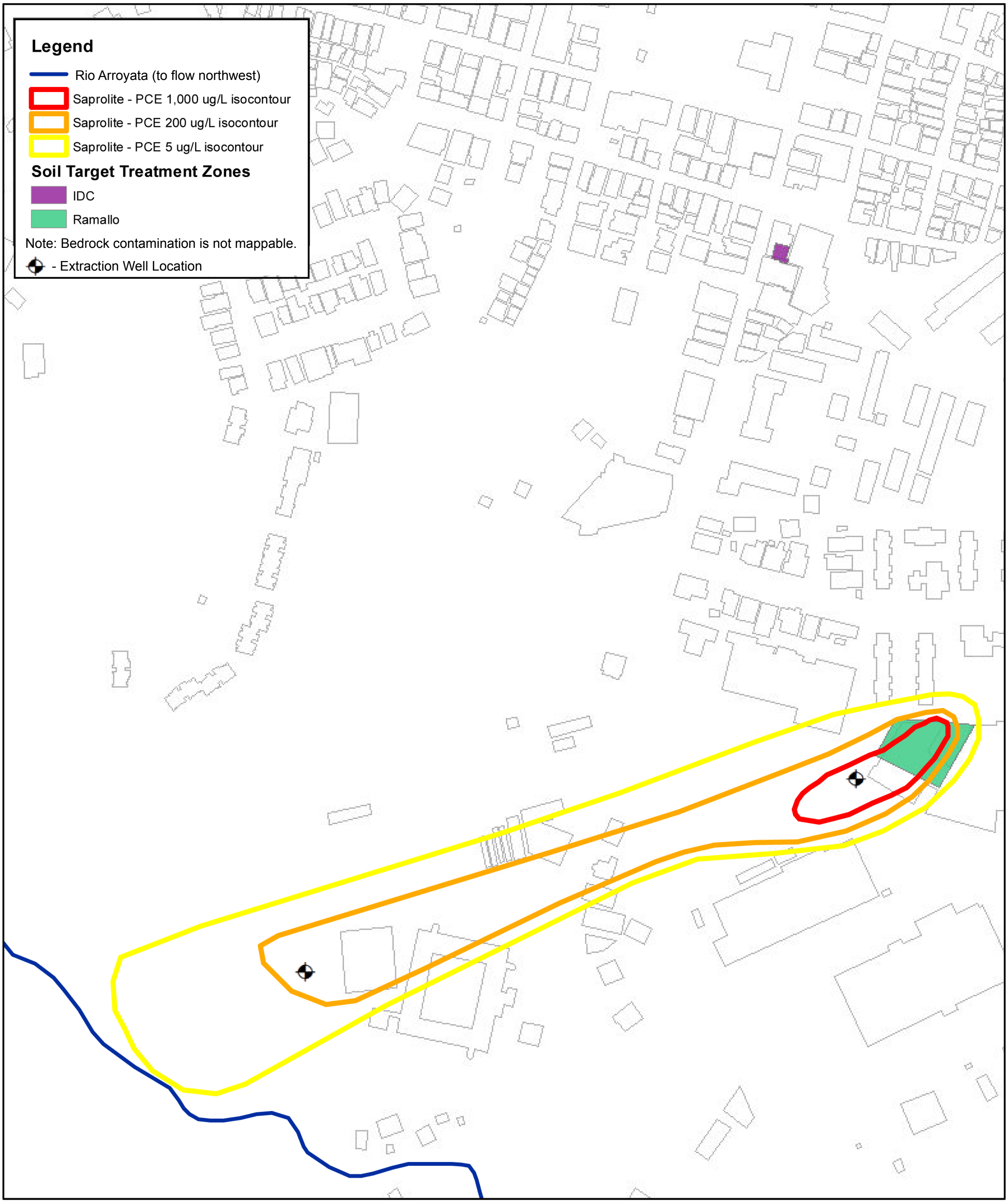

Figure 4-7
Alternative GW3 Extraction Well Locations
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

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R2-0008981

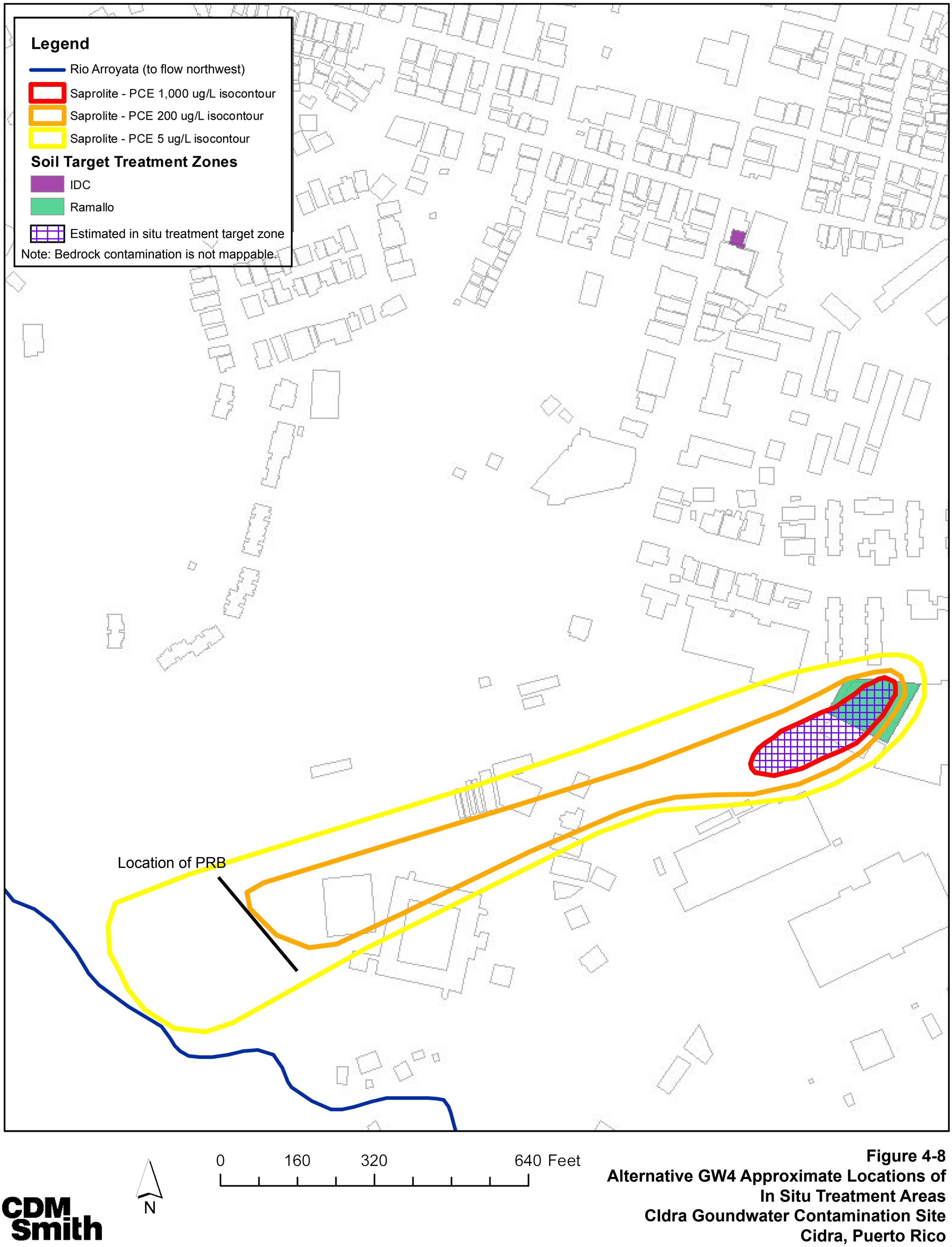

Figure 4-8
Alternative GW4 Approximate Locations of In Situ Treatment Areas
CIdra Goundwater Contamination Site
Cidra, Puerto Rico

R2-0008982

Appendix A
Cost Estimates

IDC Soil Remedial Action Alternatives

Ramallo Soil Remedial Action Alternatives

Groundwater Remedial Action Alternatives

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IDC Soil Remedial Action Alternatives

R2-0008984

Cost Estimate for Alternative IDC-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Item No.	Item Description	Extended Cost	
CAPITAL COSTS			
	Cap Installation	$	85,700
	Vapor Mitigation and Sampling	$	27,000
	Subtotal	**$**	**112,700**
	General Contractor Markup (profit, insurance etc) 20%	$	23,000
	Contingency (20%)	$	23,000
	TOTAL CAPITAL COSTS	**$**	**159,000**
OPERATION & MAINTENANCE (O&M) COSTS			
Annual O&M Costs			
	Cap Inspection per event	$	1,400
	Cap Maintenance per annum	$	2,300
PRESENT WORTH OF 30 YEAR COSTS (with discounting)			
	Total Capital Costs	$	159,000
	Present Worth of Operation and Maintenance Costs	$	46,000
	TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$**	**205,000**

Notes:
1. Present worth calculation assumes 7% discount rate after inflation is considered.

Cost Estimate Backup Sheets - Alternative IDC-S2
Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: **Individual Cost Item Backup for Alternative IDC-S2**

	Quantity	Unit	Unit Cost		Extended Cost
Cap Installation					
Construction Management & Operations - General Conditions					
Total Project Time	16	weeks			
Cap installation	1	weeks			
Pre-Mobilization Work Planning and Supports					
Project Manager	80	hr	$160	=	$12,800
Environmental Engineer	80	hr	$110	=	$8,800
Scientist	0	hr	$110	=	$0
Admin Clerk	24	hr	$75	=	$1,800
Meetings	4	LS	$2,000	=	$8,000
Permit Applications					
Project Manager		hr	$160	=	$0
Environmental Engineer		hr	$110	=	$0
Scientist	0	hr	$110	=	$0
Subcontractor Procurement					
Assume procurement of building subcontractors					
Project Manager	6	hr	$160	=	$960
Environmental Engineer	32	hr	$110	=	$3,520
Geologist	0	hr	$110		$0
Scientist	0	hr	$110	=	$0
Procurement specialist	40	hr	$110	=	$4,400
During Construction & Operations					
Project Manager (10 hrs/wk)		hr	$160	=	$0
Engineer (16 hrs/wk)		hr	$110	=	$0
Site Superintendent (10 hrs/wk)	24	hr	$100	=	$2,400
Site Trucks (2 per work days)	1	week	$250	=	$250
Health and Safety Engineer (16 hrs/wk)	0	hr	$125	=	$0
Admin Clerk (assume 4 hrs/wk)	4	hr	$75	=	$300
Subcontract management (10 hrs/week)	0	hr	$75	=	$0
Weekly calls	1	per	$500	=	$500
Two Trailers with utilities	0	LS	$35,000	=	$0
Site Security					
Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend					
Security guard	0	wk	$4,320	=	$0
Remedial Action Reports					
Project Manager	6	hr	$160	=	$960
Environmental Engineer	40	hr	$110	=	$4,400
Scientist	0	hr	$110	=	$0
Admin Clerk	0	hr	$75	=	$0
Geologist	16	hr	$110	=	$1,760
Total for Construction Management					**$51,000**
Cap Dimensions					
Area of treatment zone	500	ft^2			
Cap thickness	0.5	ft			
Cap volume	250	ft^3			
Contractor					
Mob/demob	1	LS	$5,000	=	$ 5,000
Site preparation	1	LS	$20,000	=	$ 20,000
Concrete volume	250	ft^3	$7.54	=	$ 1,900
Concrete delivery to site	1	LS	$1,000	=	$ 1,000
Concrete paving with joints, finishing and curing	56	SY	$91	=	$ 5,100
TOTAL FOR CAP INSTALLATION					**$ 33,000**
Insurance and bond (5%)					$ 1,700
TOTAL FOR CAPPING					**$ 85,700**

Description:	Individual Cost Item Backup for Alternative IDC-S2					
	Quantity	Unit	Unit Cost			Extended Cost
Vapor Mitigation Systems						
Since it is unknown how many systems are needed, it is estimated that 2 systems would be installed at IDC.						
Project Management	20	hr	$160	=	$	3,200
Offsite engineer	20	hr	$110	=	$	2,200
Office support	1	LS	$2,000	=	$	2,000
System installation	2	ea	$4,000	=	$	8,000
Onsite engineering oversight	2	day	$1,000	=	$	2,000
Subtotal for Vapor Mitigation Systems					$	17,400
Vapor Monitoring						
Assume initial sampling is completed under the RIFS budget.						
Assume vapor sampling of 2 buildings, indoor air and subslab.						
Assume 2 buildings per day.						
Days	1					
Mob/Demob	1	LS	$2,000	=	$	2,000
Environmental Engineer	10	hr	$110	=	$	1,100
Car rental	2	day	$100	=	$	200
Sample Analysis and Tabulation						
Assume CLP will provide supplies and analyze.						
VOCs	5	ea	$0	=	$	-
Data Management	10	hr	$85	=	$	850
Data Evaluation	10	hr	$155	=	$	1,550
Vapor Sampling Tech Memo						
Project Manager	6	hr	$160	=	$	960
Environmental Engineer	16	hr	$110	=	$	1,760
Chemist	8	hr	$110	=	$	880
Assume inspection of 2 Vapor Mitigation Systems						
System Inspection	1	LS	$750	=	$	750
Subtotal for Vapor Monitoring					$	10,050
TOTAL FOR VAPOR ITIGATION SYSTEMS AND SAMPLINC					**$**	**27,000**

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S2						
Cap Maintenance						
Assume 20% of cap volume is replaced every seven years						
Procurement, construction, and reporting	1	LS	$10,000	=	$	10,000
Mob/demob	1	LS	$2,000	=	$	2,000
Site preparation	1	LS	$2,000	=	$	2,000
Concrete capping material, labor and equipment costs				=	$	1,600
Insurance and bond (5%)					$	300
TOTAL FOR MAINTENANCE EVERY SEVEN YEARS					**$**	**15,900**
Annualized					**$**	**2,300**

Cost Estimate Backup Sheets - Alternative IDC-S2
Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative IDC-S2

	Quantity	Unit	Unit Cost		Extended Cost
Cap Inspection					
Days per inspection	1	days			
Labor					
Inspection	8	hr	$110	=	$880
Travel Expense and per Diem					
Van and car rental	1	day	$100	=	$100
Inspection Report					
Project Manager	1	hr	$160	=	$160
Environmental Engineer	2	hr	$110	=	$220
Admin Clerk	0	hr	$75	=	$0
TOTAL INSPECTION COST PER EVENT					**$ 1,400**

Cost Estimate Backup Sheets - Alternative IDC-S2
Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative IDC-S2

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

P = Present Worth

A= Annual amount

i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

A. Annual Inspection and Maintenance for year 1 - 30

Multiplier is (P/A) for five years minus (P/A) for year 1)

n = 30

i = 7%

The multiplier for $(P/A)_2$ = **12.409**

R2-0008990

Cost Estimate for Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

No.	Description	Cost
CAPITAL COSTS		
	General requirements	$523,000
	Building Modification	$48,500
	Soil Vapor Extraction System Construction and Startup	$148,000
	First Year Soil Vapor Extraction Operation and Maintenance	$103,360
	Containment through Concrete Capping	$34,700
	Vapor Mitigation and Sampling	$27,000
	Subtotal	$884,560
	General Contractor Markup (profit, insurance etc) 20%	$176,912
	Contingency 20%	$176,912
	Subtotal of Remedial Action	**$1,239,000**
OPERATION AND MAINTENANCE COSTS		
	Annual Operation and Maintenance for SVE System	$63,400
	Present Worth for Inspection and Maintenance (10 Years)	$446,000
	Performance Evaluation and Site Restoration	$124,000
	Present Worth for Performance Evaluation and Site Restoration	$64,000
	Annual Cost of Concrete Cap Inspection and Maintenance	$3,700
	Present Worth for Concrete Cap Inspection and Maintenance	$46,000
PRESENT WORTH		
	Total Capital Cost	$1,239,000
	Total O&M Cost	$556,000
	Total Present Worth	$1,795,000

Note: The project cost presented herein represents only feasibility study level, and is thus subject to change pending the results of the pre-design investigation, which is intended to collect sufficient data to assist in the development of remedial design and associated detailed cost estimate. Expected accuracy range of the cost estimate is -30% to +50%.

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: **Individual Cost Item Backup for Alternative IDC-S3**

	Quantity	Unit	Unit Cost			Extended Cost
Vapor Mitigation Systems						
Since it is unknown how many systems are needed, it is estimated that 2 systems would be installed at IDC.						
Project Management	20	hr	$160	=	$	3,200
Offsite engineer	20	hr	$110	=	$	2,200
Office support	1	LS	$2,000	=	$	2,000
System installation	2	ea	$4,000	=	$	8,000
Onsite engineering oversight	2	day	$1,000	=	$	2,000
Subtotal for Vapor Mitigation Systems					$	17,400
Vapor Monitoring						
Assume initial sampling is completed under the RIFS budget.						
Assume vapor sampling of 2 buildings.						
Assume 2 buildings per day for sub/slab and first floor air sampling						
Days	1					
Mob/Demob	1	LS	$2,000	=	$	2,000
Environmental Engineer	10	hr	$110	=	$	1,100
Car rental	2	day	$100	=	$	200
Sample Analysis and Tabulation						
Assume CLP will provide supplies and analyze.						
VOCs	5	ea	$0	=	$	-
Data Management	10	hr	$85	=	$	850
Data Evaluation	10	hr	$155	=	$	1,550
Vapor Sampling Tech Memo						
Project Manager	6	hr	$160	=	$	960
Environmental Engineer	16	hr	$110	=	$	1,760
Chemist	8	hr	$110	=	$	880
Assume inspection of 2 Vapor Mitigation Systems						
System Inspection	1	LS	$750	=	$	750
Subtotal for Vapor Monitoring					$	10,050
TOTAL FOR VAPOR ITIGATION SYSTEMS AND SAMPLING					**$**	**27,000**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT: Cidra	COMPUTED BY : C.G.	CHECKED BY:	
JOB NO.: 68991.3320.004	DATE : 5/9/2013	DATE CHECKED:	
CLIENT: EPA			

Description: Cost Estimate for Alternative IDC-S3

General Requirements

Project Schedule

Assume the following construction schedule:

Pre-construction work plans and meetings	2	months		
Field mobilization (permits and trailer compound establishm	0.5	months		
Building modification	1.0	months		
SVE system construction	1.5	months		
Final site restoration and demob	0.5	months		
First year operation	12	months		
Total Construction Duration	**3.5**	**months**	**15**	**weeks**
Project closeout	4	months		
Total Project Duration	**21.5**	**months**	**93**	**weeks**

General Conditions

A) Project Management and office support

Assume the following Staff for the duration of project:

Project Manager (10 hours per month)	215	hr	$160	=	$34,400
Project Engineer (12 hours per week)	1,118	hr	$110	=	$122,980
Procurement staff (4 hours per week)	373	hr	$110	=	$40,993
General office support (10 hours per mont	215	hr	$75	=	$16,125
Total management and office support					$214,498

B) Work Plan Preparation

Estimated # of Pre-Construction Work Plans Requ		10 work plans
Estimated # of Engineer Hours Required per Work		60 hours
Project Engineer	$110	per hour
Project Manager (half time)	$160	per hour
Total Work Plan Preparation Cost:		$114,000

C) Permits

Permit Specialist	120	hr	$110	=	$13,200
Project Manager	20	hr	$160	=	$3,200
Total Work Plan Preparation Cost:					$16,400

D) Onsite supervisory

Assume the following full time site supervisory staff for the duration of construction:

Site Oversight	$1,423	per day	
QC (4 hours per week)	$450	per week	
Clerk	$400	per week	
Subtotal	$7,965	per week	
Total Onsite Supervisory Staff for Construction Duration			$121,000

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative IDC-S3

General Requirements						
E) Remedial Construction Report						
Project Manager	20	hr	$160	=		$3,200
Project Engineer	200	hr	$110	=		$22,000
Project Chemist	60	hr	$110	=		$6,600
Total Work Plan Preparation Cost:						$31,800
Subtotal General Conditions:					**$497,700**	
Safety and Health Requirements						
Safety and Health Requirements to include the Site Health and Safety Officer (SHSO), personnel protective equipment additional safety and air monitoring equipment/testing. Assume visit the site once per week.						
Total Construction Dura	15	weeks				
SHSO	150	hr	$125	=		$18,750
PPE	75	day	$10	=		$750
						$19,500
Temporary Facilities						
Temporary Facilities to include the field trailers, utilities, cleaning services, and office equipment and supplies.						
Trailer rental (1 trailer)	4	month	$1,000	=		$3,500
Electricity	4	month	$200	=		$700
Cleaning service and others	4	month	$300	=		$1,050
						$5,250
TOTAL COST FOR GENERAL REQUIREMENTS						**$523,000**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT: Cidra	COMPUTED BY : C.G.	CHECKED BY:	
JOB NO.: 68991.3320.004	DATE : 5/9/2013	DATE CHECKED:	
CLIENT: EPA			

Description: Cost Estimate for Alternative IDC-S3

Building Modification

Assume that a one 20 feet section of the wall on the southern side of the IDC building footprint is demolished, including the second floor.

Also demolished is a 20 feet x 10 feet section in the ceiling

Demolition cost for building wall	500	S.F	$63.03	=	$31,600
Demolition of floorslab for sloping/modification	200	S.F	$12.70	=	$2,600
Dumpster rental	2	weeks	$1,275	=	$2,600
Handling of demolition debris	26	CY	$27.50	=	$800
Transportation of demolition debris to landfill	3	trips	$700	=	$2,100
Disposal of demolition debris	52	tons	$37	=	$2,000
Temporary doors (for demolished sections)	1	ea	$500		$500
Door Installation Labor	1	days	$288	=	$300
Modification of floor slab following demolition	3	days	$384	=	$1,200
Shoring	500	ea	$1	=	$400
Concrete for floor modification	2	CY	$204	=	$500
Post-remedial building restoration	500	S.F	$8	=	$3,900
Total cost for Building Modification					**$48,500**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative IDC-S3

Enhanced SVE System Construction and Startup

Without a field test, the flow rate and vacuum for a conceptual design are not available. Therefore, costs of similar projects are used in this cost estimate.

Project Schedule

Well installation			0.5	months		
Above ground treatment system installation			0.5	months		
System startup			0.5	months		
SVE System Construction			**1.5**	**months**	**7**	**weeks**

A) Well installation

Area of Treatment Zone	100	Ft^2			
Radius of Influence of SVE wells	5	Ft			
Radius of Influence of air injection wells	5	Ft			
Number of SVE wells	3	ea			
Number of air injection wells	2	ea			
Boring depth	20	Ft			
Hollow stem auger Mob/demob	1	LS	$5,000	=	$5,000
Decon pad	1	LS	$800	=	$800
Decon of equipment	5	Hr	$200	=	$1,000
Concrete coring	5	LS	$425	=	$2,125
Hollow stem augering	100	Ft	$35	=	$3,500
Exhaust Control and dust suppression	5	LS	$375	=	$1,875
4-inch carbon steel well casing	5	Ft	$30	=	$150
4-inch carbon steel well screen	95	Ft	$50	=	$4,750
Well surface completion	5	Ft	$500	=	$2,500
IDW handling	5	ea	$250	=	$1,250
IDW roll-off rental and disposal	1	LS	$15,000	=	$15,000
Subtotal forwell installation:					$37,950

B) Above ground piping and treatment system installation

Assume the piping will convey the extracted vapor to an above ground system housed nearby
Assume the well head apparatus will be installed above the building slab and the piping will be routed overhead
Assume treatment system for pilot study would be modified and used for the RA
for condensation, and an air compressor to enhance air flow in the subsurface. the system may be provided as a pre-packaged system.

SVE system	1	LS	$50,000	=	$50,000
SVE well head completion	5	LS	$1,260	=	$6,300
Plumbing and ducting	1	LS	$8,000	=	$8,000
Electrical Wiring and Controls	1	LS	$20,000	=	$20,000
Subtotal for SVE yard piping and above ground system					$84,300

C) SVE system startup

Assume two weeks for initial startup testing, one engineer on site for two weeks, plumber and electrician onsite for one week

Electrician	40	hr	$110	=	$4,400
Plumber	40	hr	$110	=	$4,400
Project Engineer	80	hr	$110	=	$8,800
Vapor samples	22	ea	$330	=	$7,260
Subtotal for SVE yard piping and above ground system					$24,860

TOTAL COST FOR SVE SYSTEM CONSTRUCTION AND STARTUP **$148,000**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative IDC-S3

First Year Operation and Maintenance of SVE System

Costs of similar projects are used

Assume one operator check the system once per week, assume weekly samples of influent/effluent per week for first three months, then monthly samples thereafter

Maintenance of SVE system	1	LS	$25,000	=	$25,000
One operator	208	hr	$100	=	$20,800
Supervisor for management	48	hr	$125	=	$6,000
SVE operation optimization	1	LS	$25,000	=	$25,000
Monthly reporting	12	hr	$110	=	$1,320
Annual reporting	1	LS	$16,000	=	$16,000
Vapor samples	42	ea	$220	=	$9,240
Subtotal for 5-year O&M					$103,360

Annual Operation and Maintenance of SVE System

Costs of similar projects are used

Assume one operator check the system once per week, assume influent/effluent vapor samples once per month

Maintenance of SVE system	1	LS	$10,000	=	$10,000
One operator	208	hr	$100	=	$20,800
Supervisor for management	48	hr	$125	=	$6,000
SVE operation optimization	1	LS	$10,000	=	$10,000
Monthly reporting	12	hr	$110	=	$1,320
Annual reporting	1	LS	$10,000	=	$10,000
Vapor samples	24	ea	$220	=	$5,280
Subtotal for SVE yard piping and above ground system					$63,400

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

CDM Federal Programs Corporation

PROJECT: Cidra	COMPUTED BY: C.G.	CHECKED BY:	
JOB NO.: 68991.3320.004	DATE: 5/9/2013	DATE CHECKED:	
CLIENT: EPA			

Description: Cost Estimate for Alternative IDC-S3

Performance Evaluation and Site Restoration

A. Soil Sampling					
Drilling for soil sampling					
Mob/demob of one drill rig	1	LS	$3,000	=	$3,000
Decon pad	1	LS	$800	=	$800
Decon of equipment	2	hr	$200	=	$400
Number of borings	2	borings			
Depth of boring	20	Ft			
Concrete coring	2	LS	$425	=	$850
Direct Push	2	days	$1,500	=	$3,000
Soil samples per boring	5	samples			
IDW handling	2	ea	$50	=	$100
Drum	2	ea	$80	=	$160
Boring abandonment	2	ft	$20	=	$40
Subtotal					$8,350
IDW					
Waste characterization sampling and analysis	1	ea	$500	=	$500
Drum disposal/sampling	2	ea	$200	=	$400
Subtotal					$900
Field Sampling					
Assume 2 persons 2 days x 12 hour per day for soil sampling					
Mob/demob	24	hr	$85	=	$2,040
Borings per day	1	per day			
Number of field staff	2	people			
Hours per day	12	hours			
Engineer support	16	hr	$110	=	$1,760
Project manager support	10	hr	$160	=	$1,600
Field Sampling labor	48	hr	$110	=	$5,280
Per diem	2	day	$123	=	$246
Van and car rental	2	day	$100	=	$200
Equipment & PPE	1	ea	$3,000	=	$3,000
Shipping	2	day	$150	=	$300
Misc	2	day	$200	=	$400
Subtotal					$14,826
Sample Analysis					
VOC Analysis	10	ea	$110	=	$1,100
Data Management	5	hr	$85	=	$425
Subtotal					$1,525
Treatment Performance Evaluation Report					
Assume that the data evaluation and management during sampling is included					
Project Manager/Senior Reviews	40	hr	$160	=	$6,400
Environmental Engineer	120	hr	$110	=	$13,200
Chemist	40	hr	$110	=	$4,400
GIS/MVS	16	hr	$110	=	$1,760
Clerk	24	hr	$75	=	$1,800
Total Performance Evaluation Report					$27,560
Subtotal for soil sampling					**$53,161**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith	PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:		
	JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:		
CDM Federal Programs Corporation	CLIENT:	EPA					

Description: Cost Estimate for Alternative IDC-S3
Performance Evaluation and Site Restoration

B. Site Restoration and Demobilization					
Driller mobilization/demobilization	1	LS	$4,950	=	$4,950
Well abandonment	100	ft	$20	=	$2,000
Repair of concrete	5	LS	$50	=	$250
Well abandonment oversight	3	days	$1,323	=	$3,969
Subtotal site restoration and demob					$11,169
C. Remedial Action Completion Report					
Project Manager	40	hr	$160	=	$6,400
Project Engineer	200	hr	$110	=	$22,000
Project Chemist	80	hr	$110	=	$8,800
Subtotal Report Preparation Cost:					$37,200
D. Project Closeout					
Project Manager	80	hr	$160	=	$12,800
Clerk	120	hr	$75	=	$9,000
					$21,800
TOTAL FOR PERFORMANCE EVALUATION AND SITE RESTORATION					**$ 124,000**

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith	PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:
	JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:
CDM Federal Programs Corporation	CLIENT:	EPA			

Description: Cost Estimate for Alternative IDC-S3

	Quantity	Unit	Unit Cost			Extended Cost
Concrete Capping						
Cap Dimensions						
Capped Area	500	ft^2				
Cap thickness	0.5	ft				
Cap volume	250	ft^3				
Contractor						
Mob/demob	1	LS	$5,000	=	$	5,000
Site preparation	1	LS	$20,000	=	$	20,000
Concrete material cost	250	ft^3	$7.54	=	$	1,900
Concrete delivery to site	1	LS	$1,000	=	$	1,000
Concrete paving with joints, finishing and curing	56	SY	$91.00	=	$	5,100
TOTAL FOR CAP INSTALLATION					**$**	**33,000**
Insurance and bond (5%)					$	1,700
TOTAL FOR CAPPING					**$**	**34,700**
Cap Maintenance						
Assume 20% concrete cap is replaced every seven years						
Procurement, construction management, and reporting				=	$	10,000
Mobilization cost once in every seven years				=	$	2,000
Site preparation cost once in every seven years				=	$	2,000
Concrete capping material, labor and equipment costs				=	$	1,600
Insurance and bond (5%)				=	$	300
					$	16,000
Annualized cost for concrete cap maintenance				=	**$**	**2,300**

Cost Estimate Backup Sheets - Alternative IDC-S2
Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: **Individual Cost Item Backup for Alternative IDC-S3**

	Quantity	Unit	Unit Cost		Extended Cost
Cap Inspection					
Days per inspection	1	days			
Labor					
Inspection	8	hr	$110	=	$880
Travel Expense and per Diem					
Van and car rental	1	day	$100	=	$100
Inspection Report					
Project Manager	1	hr	$160	=	$160
Environmental Engineer	2	hr	$110	=	$220
Admin Clerk	0	hr	$75	=	$0
TOTAL INSPECTION COST PER EVENT					**$ 1,400**

R2-0009001

Cost Estimate Backup Sheets - Alternative IDC-S3
Soil Vapor Extraction and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative IDC-S3

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

O&M SVE

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

P = Present Worth
A= Annual amount
i = interest rate

Multiplier is (P/A) for five years minus (P/A) for year 1)

n = 10
i = 7%

The multiplier for $(P/A)_2$ = **7.024**

O&M Concrete Cap Maintenance

For concrete capping maintenance, n = 30

The multiplier for (P/A) = **12.409**

Present Worth of single payment

$$P = A \times \frac{1}{(1+i)^n}$$

i = interest rate 7%
n = number of years 10

The multiplier for (P/A) = **0.5**

Ramallo Soil Remedial Action Alternatives

CDM Smith

Cost Estimate for Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Item Description	Extended Cost
CAPITAL COSTS	
Cap Installation	$ 186,000
Vapor Mitigation and Sampling	$ 27,000
Subtotal	**$ 213,000**
General Contractor Markup (profit, insurance etc) 20%	$ 43,000
Contingency (20%)	$ 43,000
TOTAL CAPITAL COSTS	**$ 299,000**
OPERATION & MAINTENANCE (O&M) COSTS	
Annual O&M Costs	
Cap Inspection per event	$ 1,400
Cap Maintenance per annum	$ 4,200
PRESENT WORTH	
Total Capital Costs	$ 299,000
Present Worth of Inspection and Maintenance Costs for 30 years	$ 70,000
TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$ 369,000**

Notes:

1. Present worth calculation assumes 7% discount rate after inflation is considered.
2. Expected accuracy range of the cost estimate is -30% to +50%.

Description: **Individual Cost Item Backup for Alternative R-S2**

	Quantity	Unit	Unit Cost		Extended Cost	
Vapor Mitigation Systems						
Since it is unknown how many systems are needed, it is estimated that 2 systems would be installed at Ramallo.						
Project Management	20	hr	$160	=	$	3,200
Offsite engineer	20	hr	$110	=	$	2,200
Office support	1	LS	$2,000	=	$	2,000
System installation	2	ea	$4,000	=	$	8,000
Onsite engineering oversight	2	day	$1,000	=	$	2,000
Subtotal for Vapor Mitigation Systems					$	17,400
Vapor Monitoring						
Assume initial sampling is completed under the RIFS budget.						
Assume vapor sampling of 2 buildings, indoor air and subslab.						
Assume 2 buildings per day.						
Days	1					
Mob/Demob	1	LS	$2,000	=	$	2,000
Environmental Engineer	10	hr	$110	=	$	1,100
Car rental	2	day	$100	=	$	200
Sample Analysis and Tabulation						
Assume CLP will provide supplies and analyze.						
VOCs	5	ea	$0	=	$	-
Data Management	10	hr	$85	=	$	850
Data Evaluation	10	hr	$155	=	$	1,550
Vapor Sampling Tech Memo						
Project Manager	6	hr	$160	=	$	960
Environmental Engineer	16	hr	$110	=	$	1,760
Chemist	8	hr	$110	=	$	880
Assume inspection of 2 Vapor Mitigation Systems						
System Inspection	1	LS	$750	=	$	750
Subtotal for Vapor Monitoring					$	10,050
TOTAL FOR VAPOR ITIGATION SYSTEMS AND SAMPLING					**$**	**27,000**

Cost Estimate Backup Sheets - for Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S2

	Quantity	Unit	Unit Cost		Extended Cost
Cap Installation					
Construction Management & Operations - General Conditions					
Total project time	16	weeks			
Cap installation timeperiod	2	weeks			
TOTAL CONSTRUCTION AND OPERATIONS TIME	2	weeks			
Pre-Mobilization Work Plans					
Project Manager	80	hr	$160	=	$12,800
Environmental Engineer	80	hr	$110	=	$8,800
Scientist	0	hr	$110	=	$0
Admin Clerk	40	hr	$75	=	$3,000
Meetings	4	LS	$2,000	=	$8,000
Permit Applications					
Project Manager	10	hr	$160	=	$1,600
Environmental Engineer	40	hr	$110	=	$4,400
Scientist	0	hr	$110	=	$0
Subcontractor Procurement					
Assume procurement of building subcontractors					
Project Manager	10	hr	$160	=	$1,600
Environmental Engineer	40	hr	$110	=	$4,400
Geologist	0	hr	$110		$0
Scientist	0	hr	$110	=	$0
Procurement specialist	50	hr	$110	=	$5,500
During Construction & Operations					
Project Manager (10 hrs/wk)	20	hr	$160	=	$3,200
Engineer (16 hrs/wk)	32	hr	$110	=	$3,520
Site Superintendent (10 hrs/wk)	20	hr	$100	=	$2,000
Site Trucks (2 per work days)	2	week	$250	=	$500
Health and Safety Engineer (16 hrs/wk)	32	hr	$125	=	$4,000
Admin Clerk (assume 4 hrs/wk)	8	hr	$75	=	$600
Subcontract management (10 hrs/week)	20	hr	$75	=	$1,500
Weekly calls	2	per	$500	=	$1,000
Two Trailers with utilities	0	LS	$35,000	=	$0
Site Security					
Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend					
Security guard	2	wk	$4,320	=	$8,640
Remedial Action Reports					
Project Manager	6	hr	$160	=	$960
Environmental Engineer	40	hr	$110	=	$4,400
Scientist	20	hr	$110	=	$2,200
Admin Clerk	8	hr	$75	=	$600
Geologist	20	hr	$110	=	$2,200
Total for Construction Management					**$86,000**
Cap Dimensions					
Area of treatment zone	5,000	ft^2			
Cap thickness	0.5	ft			
Cap volume	2,500	ft^3			
Contractor					
Mob/demob	1	LS	$5,000	=	$ 5,000
Site preparation	1	LS	$20,000	=	$ 20,000
Concrete delivery to site	1	LS	$1,000	=	$ 1,000
Concrete volume	2,500	ft^3	$7.54	=	$ 18,900
Concrete paving with joints, finishing and curing	556	SY	$91	=	$ 50,300
TOTAL FOR CAP INSTALLATION					**$ 95,200**
Insurance and bond (5%)					$ 4,800
TOTAL FOR CAPPING					**$ 186,000**

CDM Smith

R2-0009006

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S2						
Cap Maintenance						
Assume 20% of cap volume is replaced every seven years						
Procurement, construction, and reporting	1	LS	$10,000	=	$	10,000
Mob/demob	1	LS	$2,000	=	$	2,000
Site preparation	1	LS	$2,000	=	$	2,000
Concrete capping material, labor and equipment costs				=	$	14,040
Insurance and bond (5%)					$	1,000
TOTAL FOR MAINTENANCE EVERY SEVEN YEARS					**$**	**29,040**
Annualized					**$**	**4,200**

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S2

	Quantity	Unit	Unit Cost		Extended Cost
Cap Inspection					
Days per inspection	1	days			
Labor					
Inspection	8	hr	$110	=	$880
Travel Expense and per Diem					
Van and car rental	1	day	$100	=	$100
Inspection Report					
Project Manager	1	hr	$160	=	$160
Environmental Engineer	2	hr	$110	=	$220
Admin Clerk	0	hr	$75	=	$0
TOTAL INSPECTION COST PER EVENT				**$**	**1,400**

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S2

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

P = Present Worth

A= Annual amount

i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

A. **Annual Inspection and Maintenance for year 1 - 100**

Multiplier is (P/A) for five years minus (P/A) for year 1)

n = 30

i = 7%

The multiplier for $(P/A)_2$ = **12.409**

Cost Estimate for Alternative R-S3
Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

	Description	Cost
CAPITAL COSTS		
	General requirements	$1,268,000
	Excavation, Transportation & Disposal, and Backfill	$17,000
	In Situ Thermal Remediation - Installation, Operation, Decommissioning	$942,000
	Containment through Concrete Capping	$100,000
	Performance Evaluation and Site Restoration	$263,000
	Vapor Mitigation and Sampling	$27,000
	Subtotal	$2,617,000
	General Contractor Markup (profit, insurance etc) 20%	$523,400
	Contingency 20%	$523,400
	Total Remedial Action Capital Costs	**$3,664,000**
OPERATION AND MAINTENANCE COSTS		
	Annual Operation and Maintenance for Concrete Cap	$5,600
	Present Worth of Operations and Maintenance	**$70,000**
PRESENT WORTH		
	Total Capital Cost	$3,664,000
	Present Worth of Total Operations and Maintenance Costs	$70,000
	Total Present Worth	**$3,734,000**

Note: The project cost presented herein represents only feasibility study level, and is thus subject to change pending the results of the pre-design investigation, which is intended to collect sufficient data to assist in the development of remedial design and associated detailed cost estimate. Expected accuracy range of the cost estimate is -30% to +50%.

Cost Estimate Backup Sheets - Alternative R-S3
Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: **Individual Cost Item Backup for Alternative R-S3**

	Quantity	Unit	Unit Cost			Extended Cost
Vapor Mitigation Systems						
Since it is unknown how many systems are needed, it is estimated that 2 systems would be installed at Ramallo.						
Project Management	20	hr	$160	=	$	3,200
Offsite engineer	20	hr	$110	=	$	2,200
Office support	1	LS	$2,000	=	$	2,000
System installation	2	ea	$4,000	=	$	8,000
Onsite engineering oversight	2	day	$1,000	=	$	2,000
Subtotal for Vapor Mitigation Systems					$	17,400
Vapor Monitoring						
Assume initial sampling is completed under the RIFS budget.						
Assume vapor sampling of 2 buildings.						
Assume 2 buildings per day for sub/slab and first floor air sampling						
Days	1					
Mob/Demob	1	LS	$2,000	=	$	2,000
Environmental Engineer	10	hr	$110	=	$	1,100
Car rental	2	day	$100	=	$	200
Sample Analysis and Tabulation						
Assume CLP will provide supplies and analyze.						
VOCs	5	ea	$0	=	$	-
Data Management	10	hr	$85	=	$	850
Data Evaluation	10	hr	$155	=	$	1,550
Vapor Sampling Tech Memo						
Project Manager	6	hr	$160	=	$	960
Environmental Engineer	16	hr	$110	=	$	1,760
Chemist	8	hr	$110	=	$	880
Assume inspection of 2 Vapor Mitigation Systems						
System Inspection	1	LS	$750	=	$	750
Subtotal for Vapor Monitoring					$	10,050
TOTAL FOR VAPOR ITIGATION SYSTEMS AND SAMPLING					**$**	**27,000**

Cost Estimate Backup Sheets - Alternative R-S3
Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative R-S3

General Requirements

Project Schedule

Assume the following construction schedule:

Pre-construction work plans and meetings	4	months		
Field mobilization (permits and trailer compound establishment)	1	months		
Remedial Excavation and T&D	0.25	months		
Backfill and Compaction (lagging period)	0.25	months		
ISTR Installation and Operation	9.0	months		
Final site restoration and demob	1	months		
Total Construction Duration	**15.5**	**months**	**67**	**weeks**
Project closeout	4	months		
Total Project Duration	**19.5**	**months**	**85**	**weeks**

General Conditions

A) Project Management and office support

Assume the following Staff for the duration of project:

Project Manager (30 hours per month)	585	hr	$160	=	$93,600
Project Engineer (20 hours per week)	1,690	hr	$110	=	$185,900
Procurement staff (8 hours per week)	676	hr	$110	=	$74,360
General office support (10 hours per month)	195	hr	$75	=	$14,625
Total management and office support					$368,485

B) Work Plan Preparation

Estimated # of Pre-Construction Work Plans Required:			6 work plans
Estimated # of Engineer Hours Required per Work Plan:			120 hours
Project Engineer	$110	per hour	
Project Manager (half time)	$160	per hour	
Total Work Plan Preparation Cost:			$136,800

C) Permits

Permit Specialist	120	hr	$110	=	$13,200
Project Manager	20	hr	$160	=	$3,200
Total Work Plan Preparation Cost:					$16,400

D) Onsite supervisory

Cost Estimate Backup Sheets - Alternative R-S3
Soil Vapor Extraction and Thermal Treatment; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Assume the following full time site supervisory staff for the duration of construction:						
Site Oversight		$1,423	per day			
QC (8 hours per week)		$900	per week			
Clerk		$800	per week			
Subtotal		$8,815	per week			
Total Onsite Supervisory Staff for Construction Duration					$593,000	
E) Remedial Construction Report						
Project Manager	40	hr	$160	=		$6,400
Project Engineer	300	hr	$110	=		$33,000
Project Chemist	100	hr	$110	=		$11,000
Total Work Plan Preparation Cost:						$50,400
Subtotal General Conditions:					**$1,165,100**	
Safety and Health Requirements						
Safety and Health Requirements to include the Site Health and Safety Officer (SHSO), personnel protective equipment and supplies, and additional safety and air monitoring equipment/testing. Assume visit the site once per week.						
Total Construction Duration:		67	weeks			
SHSO	670	hr	$125	=		$83,750
PPE	335	day	$10	=		$3,350
						$87,100
Temporary Facilities						
Temporary Facilities to include the field trailers, utilities, cleaning services, and office equipment and supplies.						
Trailer rental (1 trailer)	16	month	$500	=		$7,750
Electricity	16	month	$200	=		$3,100
Cleaning service and others	16	month	$300	=		$4,650
						$15,500
TOTAL COST FOR GENERAL REQUIREMENTS						**$1,268,000**

Electrical Resistance Heating (ERH) System

CDM Smith	PROJECT: Cidra	COMPUTED BY: C.G.	CHECKED BY:
CDM Federal Programs Corporation	JOB NO.: 68991.3320.004	DATE: 5/9/2013	DATE CHECKED:
	CLIENT: EPA		

Description: Individual Cost Item Backup for Alternative RS-3

	Quantity	Unit	Unit Cost			Extended Cost
In-situ Thermal Remediation Implementation						
Assume Electrical Resistivity Heating						
	Quantity	Unit	Unit Cost			Extended Cost
Drilling costs						
Treatment area	1,000	SF				
Heating well Radius of Influence	10.0	ft				
Number of combined heating/SVE wells	3	electrodes				
Total depth of electrodes	80	ft bgs				
Temperature monitoring points	1	points				
Total number of 8.25 inch borings	4	borings				
Number of Drill Rigs	1	rigs				
Installations per rig per day	0.5	points per day				
Days for drilling	8	days				
weeks for drilling	2	weeks				
Number of additional soil vapor extraction wells	2	borings				
Total depth of SVE wells	160	ft				
Boring total	480	ft	$40	=	$	19,200
Drill cuttings per drilled foot	2.77	gal/ft				
Drill cuttings waste	1330	gal		=	$	-
Barrels of waste	33	barrels	$250	=	$	8,310
TOTAL DRILLING COSTS					**$**	**28,000**
Power Costs for ERH System Operation						
Average electrical heating power input per electrode	27.5	kW				
Total electrical heating power input	82.5	kW				
Total heating treatment time	100	days				
Design remediation energy	198000	kWh	$0.25	=	$	49,500
TOTAL ENERGY COSTS					**$**	**50,000**
Disposal and Other Costs - additional vendors						
SVE system and Treatment	$100,000	LS				$100,000
Condensate Collection and Disposal	$300,000	LS			$	300,000
TOTAL DISPOSAL/MISCELLANEOUS COSTS						**$400,000**
ERH Subcontractor costs						
Design, workplan, permits	$75,000	LS			$	75,000
Electrical Permit and Utility Connection to controller	$30,000	LS			$	30,000
Mobilization and Materials	4	heating wells	$12,500	=	$	50,000
Subsurface Installation	4	heating wells	$4,000	=	$	16,000
Surface Installation and Startup	4	heating wells	$7,000	=	$	28,000
System operation - control unit and labor	100	days	$2,000		$	200,000
Demobilization and Final Report	$50,000	LS				$50,000
Well Abandonment						
Well abandonment (grouting)	480	ft	$30	=	$	14,400
Wells abandoned per day	8	wells				
Days for abandonment	1	days				
Weeks for abandonment	0	weeks				
TOTAL SUBCONTRACTOR COSTS					**$**	**463,400**
			SVE and Thermal Treatment Total			**$942,000**

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	GR	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :		DATE CHECKED:	
CLIENT:	EPA				

Description: Individual Cost Item Backup for Alternative S4

Excavation, Transportation and Disposal (T&D) and Backfill

All contamination considered to be principal threat wastes are to be excavated. Hence all excavated materials are assumed to be hazardous wastes. Since there are no Subtitle C landfills in Puerto Rico that accept hazardous wastes, all excavated materials would be shipped offsite to mainland US.

Total Excavation Volume at Ramallo building			
Excavation area		100	square feet
Excavation depth		4	feet
Excavation volume		400	cubic feet
		20	CY
Assume excavation duration is 1 days due to multiple locations near the Ramallo building			
Excavation Labor/Equipment Costs			
Excavating Crew (unit costs based on Davis-Bacon wage determination published in January 2013)			
Equip. Op. Heavy	=	$20	per hour
Truck Dr. Heavy	=	$15	per hour
Equip. Op. Heavy	=	$20	per hour
Laborer Foreman	=	$17	per hour
Laborer (Semi-Skilled)	=	$15	per hour
Laborer (Semi-Skilled)	=	$15	per hour
Excavation Equipment			
Excavator, Hydraulic, 2 CY	=	$95	per hour
Dump Truck	=	$60	per hour
Excavation Crew and Equipment Unit Cost	=	**$257**	per hour
Duration of excavation	=	8	hours
Total cost of excavation	=	**$2,100**	

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Unit transportation costs from the site to mainland	=	$5,420	per load	(20 cubic yard boxes)
Number of loads	=	1		
Total transportation costs for disposed waste	=	$5,420		
Unit disposal costs from site to mainland	=	$135	per CY	(based on quote)
Total disposal costs	=	$2,700		
Total Transportation and Disposal Costs	=	**$8,120**		
Backfill				
Assume same Labor/Equipment costs as Excavation				
Total labor costs during backfilling (assume 12 hours)	=	$3,100		
<u>Material costs</u>				
Common Fill	=	$21	per LCY	(assume 25% bulking factor)
Total cost for common fill	=	$1,050		
Geotextile marker (allowance)	=	$500		
Backfill material testing (one sample - allowance)	=	$1,500		
Total Backfill Costs	=	**$6,150**		
TOTAL EXCAVATION, T&D AND BACKFILL COSTS	=	**$17,000**		

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative R-S3

Performance Evaluation and Site Restoration

A. Soil Sampling

Drilling for soil sampling					
Mob/demob of one drill rig	1	LS	$4,950	=	$4,950
Decon pad	1	LS	$800	=	$800
Decon of equipment	14	hr	$200	=	$2,800
Number of borings	6	borings			
Depth of boring	80	Ft			
Concrete coring	6	LS	$425	=	$2,550
Hollow stem auger drilling	480	ft	$35	=	$16,800
Exhaust Control and dust suppression	6	LS	$375	=	$2,250
Soil samples per boring	5	samples			
Soil sampling shelby tube	30	ea	$250	=	$7,500
IDW handling	6	ea	$50	=	$300
Drum	6	ea	$80	=	$480
Boring abandonment	480	ft	$20	=	$9,600
Subtotal					$48,030
IDW					
Waste characterization sampling and analysis	1	ea	$500	=	$500
Drum disposal/sampling	6	ea	$200	=	$1,200
Subtotal					$1,700
Field Sampling					
Assume 2 persons 14 days x 12 hour per day for soil sampling					
Mob/demob	60	hr	$110	=	$6,600
Borings per day	1	per day			
Number of field staff	2	people			
Hours per day	12	hours			
Engineer support	16	hr	$110	=	$1,760
Project manager support	10	hr	$160	=	$1,600
Field Sampling labor	144	hr	$110	=	$15,840
Per diem	6	day	$123	=	$738
Van and car rental	6	day	$100	=	$600
Equipment & PPE	1	ea	$3,000	=	$3,000
Shipping	6	day	$150	=	$900
Misc	6	day	$200	=	$1,200
Subtotal					$32,238

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Sample Analysis					
VOC Analysis	38	ea	$110	=	$4,125
Data Management	18.75	hr	$85	=	$1,594
Subtotal					$5,719
Treatment Performance Evaluation Report					
Assume that the data evaluation and management during sampling is included					
Project Manager/Senior Reviews	40	hr	$160	=	$6,400
Environmental Engineer	200	hr	$110	=	$22,000
Chemist	80	hr	$110	=	$8,800
GIS/MVS	24	hr	$90	=	$2,160
Clerk	40	hr	$75	=	$3,000
Total Pre-design Investigation Report					$42,360
Subtotal for soil sampling					**$130,047**
B. Site Restoration and Demobilization					
Driller mobilization/demobilization	1	LS	$4,950	=	$4,950
Well abandonment	480	ft	$20	=	$9,600
Repair of concrete	6	LS	$50	=	$300
Well abandonment oversight	15	days	$1,323	=	$19,845
Subtotal site restoration and demob					$34,695
C. Remedial Action Completion Report					
Project Manager	40	hr	$160	=	$6,400
Project Engineer	300	hr	$110	=	$33,000
Project Chemist	100	hr	$110	=	$11,000
Subtotal Report Preparation Cost:					$50,400
D. Project Closeout					
Project Manager	200	hr	$160	=	$32,000
Clerk	200	hr	$75	=	$15,000
					$47,000
TOTAL FOR PERFORMANCE EVALUATION AND SITE RESTORATION					**$ 263,000**

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith

CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Individual Cost Item Backup for Alternative R-S3

Concrete Capping	Quantity	Unit	Unit Cost		Extended Cost
Cap Dimensions					
Capped Area	5,000	ft^2			
Cap thickness	0.50	ft			
Cap volume	2,500	ft^3			
Contractor					
Mob/demob	1	LS	$5,000	=	$ 5,000
Site preparation	1	LS	$20,000	=	$ 20,000
Concrete material cost	2,500	ft^3	$7.54	=	$ 18,900
Concrete delivery to site	1	LS	$1,000.00	=	$ 1,000
Concrete paving with joints, finishing and curing	556	SY	$91	=	$ 50,300
TOTAL FOR CAP INSTALLATION				=	**$ 95,200**
Insurance and bond (5%)				=	$ 4,800
TOTAL FOR CAPPING					**$ 100,000**

Cap Maintenance		
Assume 20% concrete cap is replaced every seven years		
Procurement, construction management, reporting	=	$ 10,000
Mobilization cost once in every seven years	=	$ 2,000
Site preparation cost once in every seven years	=	$ 2,000
Concrete capping material, labor and equipment costs	=	$ 14,040
Insurance and bond (5%)	=	$ 1,000
		$ 29,040
Annualized cost for concrete cap maintenance	=	**$ 4,200**

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S3

	Quantity	Unit	Unit Cost		Extended Cost
Cap Inspection					
Days per inspection	1	days			
Labor					
Inspection	8	hr	$110	=	$880
Travel Expense and per Diem					
Van and car rental	1	day	$100	=	$100
Inspection Report					
Project Manager	1	hr	$160	=	$160
Environmental Engineer	2	hr	$110	=	$220
Admin Clerk	0	hr	$75	=	$0
TOTAL INSPECTION COST PER EVENT					**$ 1,400**

Cost Estimate Backup Sheets - Alternative R-S3
Enhanced Soil Vapor Extraction; Excavation, Disposal, and Backfill; and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Cost Estimate for Alternative R-S3

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

P = Present Worth
A= Annual amount
i = interest rate

Multiplier is (P/A) for five years minus (P/A) for year 1)

	10
	7%
The multiplier for $(P/A)_2$ =	**7.024**
O&M Concrete Cap Maintenance	
For concrete cap maintenance, n =	30
The multiplier for (P/A) =	**12.409**

R2-0009021

Cost Estimate for Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Item Description	Extended Cost	
CAPITAL COSTS		
General Conditions	$	459,000
In-situ Treatment	$	427,000
Vapor Mitigation and Sampling	$	27,000
Containment by Concrete Capping	$	100,000
Performance Evaluation and Site Restoration	$	262,000
Subtotal	**$**	**1,275,000**
General Contractor Markup (profit, insurance etc) 20%	$	255,000
Contingency (20%)	$	255,000
TOTAL CAPITAL COSTS	**$**	**1,785,000**
OPERATION & MAINTENANCE (O&M) COSTS		
Annual Insepction and Maintenance for Concrete Cap	$	5,600
PRESENT WORTH OF OPERATIONS AND MAINTENANCE	**$**	**70,000**
PRESENT WORTH OF 30 YEAR COSTS (with discounting)		
Total Capital Costs	$	1,785,000
Present Worth of Inspection and Maintenance Costs for 30 years	$	70,000
TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$**	**1,855,000**

Notes:

1. Present worth calculation assumes 7% discount rate after inflation is considered.
2. Expected accuracy range of the cost estimate is -30% to +50%.

CDM Smith

CDM Federal Programs Corporation

PROJECT: Cidra	COMPUTED BY : C.G.	CHECKED BY:	
JOB NO.: 68991.3320.004	DATE : 5/9/2013	DATE CHECKED:	
CLIENT: EPA			

Description: **Individual Cost Item Backup for Alternative R-S4**

	Quantity	Unit	Unit Cost			Extended Cost
Vapor Mitigation Systems						
Since it is unknown how many systems are needed, it is estimated that 2 systems would be installed at Ramallo.						
Project Management	20	hr	$160	=	$	3,200
Offsite engineer	20	hr	$110	=	$	2,200
Office support	1	LS	$2,000	=	$	2,000
System installation	2	ea	$4,000	=	$	8,000
Onsite engineering oversight	2	day	$1,000	=	$	2,000
Subtotal for Vapor Mitigation Systems					$	17,400
Vapor Monitoring						
Assume initial sampling is completed under the RIFS budget.						
Assume vapor sampling of 2 buildings.						
Assume 2 buildings per day for sub/slab and first floor air sampling						
Days	1					
Mob/Demob	1	LS	$2,000	=	$	2,000
Environmental Engineer	10	hr	$110	=	$	1,100
Car rental	2	day	$100	=	$	200
Sample Analysis and Tabulation						
Assume CLP will provide supplies and analyze.						
VOCs	5	ea	$0	=	$	-
Data Management	10	hr	$85	=	$	850
Data Evaluation	10	hr	$155	=	$	1,550
Vapor Sampling Tech Memo						
Project Manager	6	hr	$160	=	$	960
Environmental Engineer	16	hr	$110	=	$	1,760
Chemist	8	hr	$110	=	$	880
Assume inspection of 2 Vapor Mitigation Systems						
System Inspection	1	LS	$750	=	$	750
Subtotal for Vapor Monitoring					$	10,050
TOTAL FOR VAPOR ITIGATION SYSTEMS AND SAMPLING					**$**	**27,000**

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Individual Cost Item Backup for Alternative R-S4

General Conditions

Project Schedule

Assume the following project schedule:

Pre-Construction Work Plans and Meetings (RA Work) - assume about 5 months or 20 we	20	weeks
Field Trailer Compound Establishment - assume 3 weeks	3	weeks
Site Preparation (Designate areas/zones, clearing)	1	weeks
Fracturing and in-situ treatment	1	weeks
Containment by Concrete Capping	1	weeks
Final Site Restoration and Demob - assume 3 weeks	3	weeks
Total Construction Duration	9	weeks
Project Closeout (assume about 3 months or 12 weeks)	12	weeks
Total Project Duration	**41**	**weeks**

	Quantity	Unit	Unit Cost		Extended Cost
Pre-Mobilization Work Plans and Management					
Project Manager (30 hours per month)	300	hr	$160	=	$48,000
Project Engineer (20 hours per week)	824	hr	$110	=	$90,640
Procurement staff (8 hours per week)	330	hr	$110	=	$36,300
General office support (10 hours per month)	103	hr	$75	=	$7,725
Permit Applications					
Project Manager	20	hr	$160	=	$3,200
Environmental Engineer	120	hr	$110	=	$13,200
Subcontractor Procurement					
Assume procurement of driller, IDW, laboratory, drilling and injection subcontractors					
Project Manager	60	hr	$160	=	$9,600
Environmental Engineer	40	hr	$110	=	$4,400
Geologist	30	hr	$110		$3,300
Scientist	30	hr	$110	=	$3,300
Procurement specialist	50	hr	$110	=	$5,500
During Construction & Operations					
Project Manager (10 hrs/wk)	92	hr	$160	=	$14,720
Engineer (16 hrs/wk)	147	hr	$110	=	$16,192
Site Superintendent (10 hrs/wk)	92	hr	$100	=	$9,200

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Site Trucks (2 per work days)	9	week	$250	=	$2,300
Admin Clerk (assume 4 hrs/wk)	37	hr	$75	=	$2,760
Subcontract management (10 hrs/week)	92	hr	$75	=	$6,900
Meetings	18	LS	$500	=	$9,000
Weekly calls	9	per	$500	=	$4,600
Temporary Facilities					
Two Trailers with utilities	1	LS	$35,000	=	$35,000
Health and Safety					
PPE (assume $10 per day per worker, avg 6 workers)	46	day	$60	=	$2,760
Health and Safety Engineer (16 hrs/wk)	147	hr	$125	=	$18,400
Site Security					
Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend					
Security guard	9	wk	$4,320	=	$39,800
Survey					
Assume 2-person crew, 12 hrs/wk at $62/hr	9	wk	$1,488	=	$13,700
Remedial Action Reports					
Project Manager	40	hr	$160	=	$6,400
Environmental Engineer	240	hr	$110	=	$26,400
Scientist	80	hr	$110	=	$8,800
Admin Clerk	40	hr	$75	=	$3,000
Geologist	120	hr	$110	=	$13,200
TOTAL COST FOR GENERAL CONDITIONS					**$459,000**

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT: Cidra	COMPUTED BY: C.G.	CHECKED BY:	
JOB NO.: 68991.3320.004	DATE: 5/9/2013	DATE CHECKED:	
CLIENT: EPA			

Description: Individual Cost Item Backup for Alternative S4

Hydraulic Fracturing and Amendment Injection						
Area of treatment zone	1,000	ft^2				
Radius of Influence	15.0	ft				
Total depth	100	ft bgs				
Treatment zone thickness	90	ft				
Estimated total porosity	0.25	--				
Assume soil bulk density	100	lb/ft^3				
Mass of soil in treatment zone	9,000,000	lbs				
Fracturing and Injection Point Installation Details						
Number of fracture/injection points	6	points				
Treatment zone volume	90,000	ft^3				
Volume pore space	22,500	ft^3				
Drilling Contractor						
Boring total	600	ft	$25	=	$	15,000
Driller Mob/demob	1	LS	$5,000	=	$	5,000
Drill cuttings per drilled foot	2.6	gal/ft				
Drill cuttings waste	1560	gal				
Barrels of waste	39	barrels	$250	=	$	9,750
Fracturing and Injection Contractor						
Number of Rigs	1	rigs				
Mob/demob	1	LS	$45,000	=	$	45,000
Fracture/Injection points completed per day	1	points per day				
Fracture/Injection contractor	6	days	$15,000	=	$	90,000
TOTAL FOR AMENDMENT INJECTION					**$**	**164,750**
Amendment Details						
Percentage amendment by soil mass	0.50%	lb amendment/lb soil				
Mass of amendment required	45,000	lbs	$1.90	=	$	85,500
Truck delivery	1	LS	$20,000	=	$	20,000
TOTAL FOR AMENDMENTS					**$**	**105,500**

Assume two injection events, the first one with 45,000 lbs and a second event, the cost of which is 50% of first injection event.

Subtotal for two injection events	$	406,000
Insurance and bond (5%)	$	21,000
TOTAL IN-SITU TREATMENT	**$**	**427,000**

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Individual Cost Item Backup for Alternative S4

	Quantity	Unit	Unit Cost			Extended Cost
Concrete Capping						
Cap Dimensions						
Capped Area	5,000	ft^2				
Cap thickness	0.50	ft				
Cap volume	2,500	ft^3				
Contractor						
Mob/demob	1	LS	$5,000	=	$	5,000
Site preparation	1	LS	$20,000	=	$	20,000
Concrete material cost	2,500	ft^3	$7.54	=	$	18,900
Concrete Delivery to site	1	LS	$1,000	=	$	1,000
Concrete paving with joints, finishing and curing	556	SY	$91	=	$	50,300
TOTAL FOR CAP INSTALLATION					**$**	**95,200**
Insurance and bond (5%)					$	4,800
TOTAL FOR CAPPING					**$**	**100,000**

Cap Maintenance

Assume 20% concrete cap is replaced every seven years

Procurement, construction management, and reporting	=	$	10,000
Mobilization cost once in every seven years	=	$	2,000
Site preparation cost once in every seven years	=	$	2,000
Concrete capping material, labor and equipment costs	=	$	14,040
Insurance and bond (5%)	=	$	1,000
		$	29,040
Annualized cost for concrete cap maintenance	=	**$**	**4,200**

Cost Estimate Backup Sheets - Alternative R-S2
Containment
CIdra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Alternative R-S4

	Quantity	Unit	Unit Cost		Extended Cost
Cap Inspection					
Days per inspection	1	days			
Labor					
Inspection	8	hr	$110	=	$880
Travel Expense and per Diem					
Van and car rental	1	day	$100	=	$100
Inspection Report					
Project Manager	1	hr	$160	=	$160
Environmental Engineer	2	hr	$110	=	$220
Admin Clerk	0	hr	$75	=	$0
TOTAL INSPECTION COST PER EVENT				**$**	**1,400**

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description:	Individual Cost Item Backup for Alternative R-S4				
Performance Evaluation and Site Restoration					
A. Soil Sampling					
Drilling for soil sampling					
Mob/demob of one drill rig	1	LS	$4,950	=	$4,950
Decon pad	1	LS	$800	=	$800
Decon of equipment	6	hr	$200	=	$1,200
Number of borings	6	borings			
Depth of boring	80	Ft			
Concrete coring	6	LS	$425	=	$2,550
Hollow stem auger drilling	480	ft	$35	=	$16,800
Exhaust Control and dust suppression	6	LS	$375	=	$2,250
Soil samples per boring	5	samples			
Soil sampling shelby tube	30	ea	$250	=	$7,500
IDW handling	6	ea	$50	=	$300
Drum	6	ea	$80	=	$480
Boring abandonment	480	ft	$20	=	$9,600
Subtotal					$46,430
IDW					
Waste characterization sampling and analysis	1	ea	$500	=	$500
Drum disposal/sampling	6	ea	$200	=	$1,200
Subtotal					$1,700
Field Sampling					
Assume 2 persons 14 days x 12 hour per day for soil sampling					
Mob/demob	60	hr	$85	=	$5,100
Borings per day	1	per day			
Number of field staff	2	people			
Hours per day	12	hours			
Engineer support	16	hr	$110	=	$1,760
Project manager support	10	hr	$160	=	$1,600
Field Sampling labor	144	hr	$110	=	$15,840
Per diem	6	day	$123	=	$738
Van and car rental	6	day	$100	=	$600
Equipment & PPE	1	ea	$3,000	=	$3,000
Shipping	6	day	$150	=	$900
Misc	6	day	$200	=	$1,200
Subtotal					$30,738
Sample Analysis					
VOC Analysis	38	ea	$110	=	$4,125
Data Management	19	hr	$85	=	$1,615
Subtotal					$5,740

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Treatment Performance Evaluation Report					
Assume that the data evaluation and management during sampling is included					
Project Manager/Senior Reviews	40	hr	$160	=	$6,400
Environmental Engineer	200	hr	$110	=	$22,000
Chemist	80	hr	$110	=	$8,800
GIS/MVS	24	hr	$90	=	$2,160
Clerk	40	hr	$75	=	$3,000
Total Performance Evaluation Report					$42,360
TOTAL SOIL SAMPLING COSTS					**$126,968**
B. Site Restoration and Demobilization					
Driller mobilization/demobilization	1	LS	$4,950	=	$4,950
Well abandonment	600	ft	$20	=	$12,000
Repair of concrete	6	LS	$50	=	$300
Well abandonment oversight	15	days	$1,323	=	$19,845
Subtotal site restoration and demob					$37,095
C. Remedial Action Completion Report					
Project Manager	40	hr	$150	=	$6,000
Project Engineer	300	hr	$110	=	$33,000
Project Chemist	100	hr	$110	=	$11,000
Subtotal Report Preparation Cost:					$50,000
D. Project Closeout					
Project Manager	200	hr	$150	=	$30,000
Clerk	200	hr	$85	=	$17,000
					$47,000
TOTAL FOR PERFORMANCE EVALUATION AND SITE RESTORATION					**$ 262,000**

Cost Estimate Backup Sheets - Alternative R-S4
In Situ Chemical Treatment and Containment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

CDM Smith
CDM Federal Programs Corporation

PROJECT:	Cidra	COMPUTED BY :	C.G.	CHECKED BY:	
JOB NO.:	68991.3320.004	DATE :	5/9/2013	DATE CHECKED:	
CLIENT:	EPA				

Description: Individual Cost Item Backup for Alternative S4

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

P = Present Worth

A= Annual amount

i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

A. **Cap Maintenance - Year 1 through 30**

Multiplier is (P/A) for five years minus (P/A) for year 1)

n = 30

i = 7%

The multiplier for $(P/A)_2$ = **12.409**

R2-0009031

Groundwater Remedial Action Alternatives

CDM Smith

Cost Estimate for Alternative GW2
Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Item No.	Item Description	Extended Cost
CAPITAL COSTS		
1.	Groundwater Extraction and Treatment System	$ 2,166,000
	Subtotal	**$ 2,166,000**
	General Contractor Markup (profit, insurance etc) 20%	$ 433,000
	Contingency (20%)	$ 433,000
	TOTAL CAPITAL COSTS	**$ 3,032,000**
OPERATION & MAINTENANCE (O&M) COSTS		
Annual O&M Costs		
2.	O&M Costs	$ 380,000
3.	Long Term Monitoring (1 quarterly event for years 1 and 2)	$ 360,000
4.	Long Term Monitoring (1 annual event for years 3-30)	$ 90,000
PRESENT WORTH OF 30 YEAR COSTS (with discounting)		
	Total Capital Costs	$ 3,032,000
	Total O&M Costs	$ 4,715,000
	Total Monitoring Costs	$ 1,674,000
	TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$ 9,421,000**

Notes:

1. Present worth calculation assumes 7% discount rate after inflation is considered.

Cost Estimate Backup Sheets - Alternative GW2
Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Descriptio Individual Cost Item Backup for Groundwater Alternative 2

		Quantity	Unit	Unit Cost		Extended Cost
No. 1	**Extraction and Treatment System**					
1a.	**Construction Management & Operations - General Conditions**					
	Drilling time period	5	weeks			
	Installation and start up time	20	weeks			
	TOTAL CONSTRUCTION TIME	25	weeks			
	General Contractor Markup (profit, insurance etc) 20%					
	Pre-Mobilization Work Planning, management, and preparation of plans					
	Project Manager	150	hr	$160	=	$24,000
	Environmental Engineer	150	hr	$110	=	$16,500
	Scientist	150	hr	$110	=	$16,500
	Admin Clerk	150	hr	$75	=	$11,250
	Meetings	6	LS	$3,000	=	$18,000
	Permit Applications					
	Project Manager	20	hr	$160	=	$3,200
	Environmental Engineer	160	hr	$110	=	$17,600
	Permit Fees for Gas, Power, Air & Water Discharge					$40,000
	Subcontractor Procurement					
	Assume procurement of driller, IDW, laboratory, groundwater treatment subcontractors					
	Project Manager	60	hr	$160	=	$9,600
	Environmental Engineer	60	hr	$110	=	$6,600
	Geologist	60	hr	$110		$6,600
	Scientist	60	hr	$110	=	$6,600
	Procurement specialist	200	hr	$110	=	$22,000
	During Construction					
	Project Manager (10 hrs/wk)	248	hr	$160	=	$39,719
	Engineer (16 hrs/wk)	397	hr	$110	=	$43,691
	Site Superintendent (40 hrs/wk)	993	hr	$100	=	$99,297
	Site Trucks (2 per work days)	25	week	$250	=	$6,206
	Per Diem (2 people per work days)	50	day	$323	=	$16,036
	Health and Safety Engineer (16 hrs/wk)	397	hr	$125	=	$49,648
	Admin Clerk (assume 4 hrs/wk)	99	hr	$75	=	$7,447
	Subcontract management (10 hrs/week)	248	hr	$75	=	$18,618
	Weekly calls	25	per	$1,000	=	$24,824
	Two Trailers with utilities	2	LS	$35,000	=	$70,000
	Site Security					
	Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend at $20/hr					
	Security guard	25	wk	$2,160	=	$53,620
	Remedial Action Reports					
	Project Manager	40	hr	$160	=	$6,400
	Environmental Engineer	160	hr	$110	=	$17,600
	Scientist	80	hr	$110	=	$8,800
	Admin Clerk	40	hr	$75	=	$3,000
	Geologist	80	hr	$110	=	$8,800
	Total for Construction Management					**$673,000**

			Quantity	Unit	Unit Cost		Extended Cost
1b.	**P&T Implementation**						
	Drilling costs						
	Treatment area		406,400	SF			
	Number of extraction wells		4	each	$ 15,000.00		$ 60,000.00
	Total depth of each well		110	ft bgs	$ 450.00		$ 49,500.00
	Well - 10-inch hollow stem auger borehole drilling		440	ft	$ 65.00		$ 28,600.00
	6-inch stainless steel screen		200	ft	$ 150.00		$ 30,000.00
	6-inch stainless steel casing		240	ft	$ 60.00		$ 14,400.00
	Well development		120	hours	$ 400.00		$ 48,000.00
	Pump installation and testing		4	each	$ 5,000.00		$ 20,000.00
	Number of Drill Rigs		1	rigs			
	Installations per rig per day		0.33	points per day			
	Days for drilling		12	days			
	Days for development		12	days			
	Weeks for drilling		5	weeks			
	Drill cuttings per drilled foot		16.18	gal/ft			
	Drill cuttings waste		7120	gal			
	Barrels of waste Disposal		178	barrels	$ 250.00	=	$ 44,499
	TOTAL DRILLING COSTS						**$ 295,000**
	Earthwork						
	Trenching and piping						
	Assume 3440 ft pipe required to treatment plant	3440					
	Assume 1540 ft pipe required to discharge point	1540					
	Assume discharge to Rio Arroyata						
	Excavated for 4" PVC pipe (trench is 5 ft deep 2 ft wide)		1,844	CY	$ 6.65	=	$ 12,266
	4-inch PVC pressure piping (RSMeans 02500.750.4040)		3,440	LF	$ 6.85	=	$ 23,564
	6-inch PVC pressure piping (RS Means 221113.74.44.90)		1,540	LF	$ 9.46	=	$ 14,568
	Backfill		922	CY	$ 15.00	=	$ 13,833
	Electrical		500	LF	$ 2.00	=	$ 1,000

well pump controls and power	3,440	LF	$ 15.00	=	$	51,600
TOTAL EARTHWORK COSTS					$	116,831
Miscellaneous items					$	200,000
Treatment System						
Treatment system enclosure	1	EA	$ 35,000.00	=	$	35,000
Extraction Pumps at 30 gpm each	4	EA	$ 4,000.00	=	$	16,000
Pre-packaged groundwater treatment system	1	LS	$ 163,000.00	=	$	163,000
Green Sand Filter or Bag Filter	4		included			
Potassium permanganate off gas treatment	1		included			
Influent and effluent Tanks (2000 Gal)	1		included			
Transfer Pump (centrifugal); includes spare	2		included			
Air Stripper package	1		included			
Sump w/pump	1		included			
Off gas treatment system	1		included			
Piping, fitting and support within building	1		included			
Valves	1		included			
I&C	1		included			
HVAC	1		included			
Light	1		included			
Electrical power supplies, wiring, cabl	1		included			
Subtotal Equipment Cost				=	$	214,000
Assume 100% of cost for installation				=	$	214,000
Cost for shipping and handling				=	$	12,500
Total treatment facility cost				=	$	440,500
TOTAL TREATMENT COMPONENTS COSTS				=	**$**	**881,000**
TOTAL SUBCONTRACTOR COSTS					**$**	**1,492,831**
				P&T Total		**$2,166,000**

Cost Estimate Backup Sheets - Alternative GW2
Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description:	Individual Cost Item Backup for Groundwater Alternative 2					
		Quantity	Unit	Unit Cost		Extended Cost
No. 2	**Annual Groundwater Treatment Plant O&M Cost**					
	Labor cost					
	Assume one operator for 52 weeks at 16 hours a week					
	Operator	832	hrs/yr	$85	=	$70,720
	Supervision at 20%				=	$14,144
	Home office support at 20%				=	$14,144
	TC 0				=	$99,008
	Analysis cost					
	Assume treated groundwater and off-gas will be sampled once a week					
	Samples					
	VOCs	1	samples	$80	=	$80
	VOCs (TO-15 vapor)	1	samples	$190	=	$190
	metals	1	samples	$120	=	$120
	wet chemistry (TSS, TDS, Alk, pH)	1	samples	$50	=	$50
	TOTAL ANNUAL COST FOR SAMPLE ANALYSIS				=	$22,880
	Power cost					
	Assume the blower is 10 HP and the discharge pump would be 5 HP and transfer pump is 2 HP.					
	Total pumping horsepower	25	hp			
	Building power draw	15	kW			
	Total power draw	33.75	kW			
	Unit cost of Power per kilowatt hour	$ 0.25	kW/hr	33.75 kW/hr		
	Total power consumption per year	295,650				
	Contingency at 10%	29,565				
	TOTAL ANNUAL POWER COST				=	$81,304
	Maintenance Cost					
	Carbon changeout per year	1	LS	$50,000	=	$50,000
	Parts and supplies (10% of equipment cost)	1	LS	$21,400	=	$21,400
	Shipping at 10%				=	$2,140
	ESTIMATED MAINTENANCE COST					$73,540
	Reporting					
	Annual O&M Report				=	$20,000
	Data management				=	$20,000
	Subtotal Annual O&M Cost				=	$316,732
	Contingency at 20%				=	$63,346
	TOTAL ANNUAL O&M COST					**$380,000**

Cost Estimate Backup Sheets - Alternative GW2
Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Groundwater Alternative 2

		Quantity	Unit	Unit Cost		Extended Cost
No. 3	**Long Term Monitoring of Wells**					
	Number of samples	20	samples			
	Number of samplers	2	people			
	Number of 12 hour workdays	5	days			
	Sampling Project Planning (e.g., Staffing, Lab Procurement, Obtaining Equipment)					
	General Contractor Markup (profit, insurance etc) 20%					
	Project Manager	16	hr	$160	=	$2,560
	Project Engineer	50	hr	$110	=	$5,500
	Procurement Specialist	40	hr	$110	=	$4,400
	Field Sampling Labor					
	Mob/demob	60	hr	$110	=	$6,600
	Sampling	120	hr	$110	=	$13,200
	Travel Expense and per Diem					
	Van and car rental	5	day	$95	=	$475
	Sampling Equipment, Shipping, Consumable Supplies					
	Equipment & PPE	1	ea	$3,500	=	$3,500
	Shipping	5	day	$200	=	$1,000
	Misc	5	day	$75	=	$375
	Sampling Analysis					
	VOCs	27	ea	$80	=	$2,160
	MEE	27	ea	$120	=	$3,240
	TOC	27	ea	$30	=	$810
	Nitrate	27	ea	$25	=	$675
	Sulfate	27	ea	$25	=	$675
	Ferrous Iron	27	ea	$18	=	$486
	Chloride	27	ea	$15	=	$405
	Alkalinity	27	ea	$20	=	$540
	Metals	27	ea	$120	=	$3,240
	Data Validation					
	Assume samples validated @ 1 hr per sample					
	Samples management/validation	243	hr	$110	=	$26,730
	Sampling Report					
	Project Manager	16	hr	$160	=	$2,560
	Environmental Engineer	40	hr	$110	=	$4,400
	Geologist	40	hr	$110	=	$4,400
	Admin Clerk	16	hr	$75	=	$1,200
	TOTAL GROUNDWATER SAMPLING COST PER EVENT				**$**	**90,000**

Cost Estimate Backup Sheets - Alternative GW2
Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Groundwater Alternative 2

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.
This is a problem of the form find (P given A, i, n) or (P/A,i,n)
P = Present Worth
A= Annual amount
i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

A. **Long Term Monitoring - year 3- 30** $0.00

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	30
i =	7%
The multiplier for $(P/A)_2$ =	**12.409**
n =	2
i =	7%
The multiplier for $(P/A)_2$ =	**1.808**
Net	**10.601**

R2-0009038

Cost Estimate for Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Item No.	Item Description	Extended Cost	
CAPITAL COSTS			
1.	Groundwater Extraction and Treatment System	$	1,939,000
	Subtotal	**$**	**1,939,000**
	General Contractor Markup (profit, insurance etc) 20%	$	388,000
	Contingency (20%)	$	388,000
	TOTAL CAPITAL COSTS	**$**	**2,715,000**
OPERATION & MAINTENANCE (O&M) COSTS			
Annual O&M Costs			
2.	O&M Costs	$	362,000
3.	Long Term Monitoring (quarterly event for years 1 and 2)	$	360,000
4.	Long Term Monitoring (annual event for years 3-30)	$	90,000
PRESENT WORTH OF 30 YEAR COSTS (with discounting)			
	Total Capital Costs	$	2,715,000
	Total O&M	$	4,492,000
	Total Monitoring Costs	$	1,674,000
	TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$**	**8,881,000**

Notes:
1. Present worth calculation assumes 7% discount rate after inflation is considered.

Cost Estimate Backup Sheets - Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Groundwater Alternative 3

		Quantity	Unit	Unit Cost		Extended Cost
No. 1	**Extraction and Treatment System**					
1a.	**Construction Management & Operations - General Conditions**					
	Drilling time period	2.4	weeks			
	Installation and start up time	20	weeks			
	TOTAL CONSTRUCTION TIME	22	weeks			
	Pre-Mobilization Work Plans					
	Project Manager	150	hr	$160	=	$24,000
	Environmental Engineer	150	hr	$110	=	$16,500
	Scientist	150	hr	$110	=	$16,500
	Admin Clerk	150	hr	$75	=	$11,250
	Meetings	6	LS	$3,000	=	$18,000
	Permit Applications					
	Project Manager	20	hr	$160	=	$3,200
	Environmental Engineer	160	hr	$110	=	$17,600
	Permit Fees for Gas, Power, Air & Water Discharge					$40,000
	Subcontractor Procurement					
	Assume procurement of driller, IDW, laboratory, groundwater treatment subcontractors					
	Project Manager	60	hr	$160	=	$9,600
	Environmental Engineer	60	hr	$110	=	$6,600
	Geologist	60	hr	$110		$6,600
	Scientist	60	hr	$110	=	$6,600
	Procurement specialist	200	hr	$110	=	$22,000
	During Construction					
	Project Manager (10 hrs/wk)	224	hr	$160	=	$35,859
	Engineer (16 hrs/wk)	359	hr	$110	=	$39,445
	Site Superintendent (40 hrs/wk)	896	hr	$100	=	$89,648
	Site Trucks (2 per work days)	22	week	$250	=	$5,603
	Per Diem (2 people per work days)	45	day	$323	=	$14,478
	Health and Safety Engineer (16 hrs/wk)	359	hr	$125	=	$44,824
	Admin Clerk (assume 4 hrs/wk)	90	hr	$75	=	$6,724
	Subcontract management (10 hrs/week)	224	hr	$75	=	$16,809
	Weekly calls	20	per	$500	=	$10,000
	Two Trailers with utilities	2	LS	$35,000	=	$70,000
	Site Security					
	Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend at $20/hr					
	Security guard	22	wk	$2,160	=	$48,410
	Remedial Action Reports					
	Project Manager	40	hr	$160	=	$6,400
	Environmental Engineer	160	hr	$110	=	$17,600
	Scientist	80	hr	$110	=	$8,800
	Admin Clerk	40	hr	$75	=	$3,000
	Geologist	80	hr	$110	=	$8,800
	TOTAL FOR CONSTRUCTION MANAGEMENT					**$625,000**

			Quantity	Unit	Unit Cost		Extended Cost
1b.	**P&T Implementation**						
	Drilling costs						
	Treatment area		173,866	SF			
	Number of extraction wells		2	each	$ 15,000.00		$ 30,000
	Total depth of each well		110	ft bgs	$ 450.00		$ 49,500
	Well - 10-inch hollow stem auger borehole drilling		220	ft	$ 65.00		$ 14,300
	6-inch stainless steel screen		100	ft	$ 150.00		$ 15,000
	6-inch stainless steel casing		120	ft	$ 60.00		$ 7,200
	Well development		60	hours	$ 400.00		$ 24,000
	Pump installation and testing		2	each	$ 5,000.00		$ 10,000
	Number of Drill Rigs		1	rigs			
	Installations per rig per day		0.33	points per day			
	Days for drilling		6	days			
	Days for well development		6	days			
	Weeks for drilling		2.4	weeks			
	Drill cuttings per drilled foot		16.18	gal/ft			
	Drill cuttings waste		3560	gal			
	Barrels of waste		89	barrels	$ 250.00	=	$ 22,250
	TOTAL DRILLING COSTS						**$ 173,000**
	Earthwork						
	Trenching and piping						
	Assume 2760 ft pipe required to treatment plant	2500					
	Assume 1540 ft pipe required to discharge point	1540					
	Assume discharge to Rio Arroyata						
	Excavated for 4" and 6" PVC pipe (trench is 5 ft deep 2 ft wide)		1496	CY	$ 6.65	=	$ 9,950
	4-inch PVC pressure piping (RSMeans 02500.750.4040)		2500	LF	$ 6.85	=	$ 17,125
	6-inch PVC pressure piping (RS Means 221113.74.44.90)		1540	LF	$ 9.46	=	$ 14,568
	Backfill		748	CY	$ 15.00	=	$ 11,222
	Electrical		500	LF	$ 2.00	=	$ 1,000
	well pump controls and power		2500	LF	$ 15.00	=	$ 37,500

Cost Estimate Backup Sheets - Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

TOTAL EARTHWORK COSTS					$	91,366
Miscellaneous items					$	200,000
Treatment system enclosure						
Treatment system enclosure	1	EA	$ 35,000.00	=	$	35,000
Extraction Pumps at 30 gpm each	2	EA	$ 4,000.00	=	$	8,000
Groundwater treatment system	1	LS	$ 163,000.00	=	$	163,000
Green Sand Filter or Bag Filter	4		included			
Potassium permanganate off gas treatment	1		included			
Influent and effluent Tanks (2000 Gal)	1		included			
Transfer Pump (centrifugal); includes spare	2		included			
Air Stripper package	1		included			
Sump w/pump	1		included			
Off gas treatment system	1		included			
Piping, fitting and support within building	1		included			
Valves	1		included			
I&C	1		included			
HVAC	1		included			
Light	1		included			
Electrical power supplies, wiring, cable	1		included			
Subtotal Equipment Cost				=	$	206,000.00
Assume 100% of cost for installation				=	$	206,000.00
Cost for shipping and handling				=	$	12,500
Total treatment facility cost				=	$	424,500
TOTAL TREATMENT COMPONENTS COSTS				=	**$**	**849,000**
TOTAL SUBCONTRACTOR COSTS						**$1,313,366**
				P&T Total		**$1,939,000**

R2-0009041

Cost Estimate Backup Sheets - Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description:	Individual Cost Item Backup for Groundwater Alternative 3						
		Quantity	Unit	Unit Cost		Extended Cost	
No. 2	**Annual Groundwater Treatment Plant O&M Cost**						
	Labor cost						
	Assume one operator for 52 weeks at 16 hours a week						
	Operator	832	hrs/yr	$85	=	$70,720	
	Supervision at 20%				=	$14,144	
	Home office support at 20%				=	$14,144	
	TOTAL ANNUAL LABOR COST				=	$99,008	
	Analysis cost						
	Assume treated groundwater and off-gas will be sampled once a week						
	Samples						
	VOCs	1	samples	$80	=	$80	
	VOCs (TO-15 vapor)	1	samples	$190	=	$190	
	metals	1	samples	$120	=	$120	
	wet chemistry (TSS, TDS, Alk, pH)	1	samples	$50	=	$50	
	TOTAL ANNUAL COST FOR SAMPLE ANALYSIS				=	$22,880	
	Power cost						
	Assume the blower is 10 HP and the discharge pump would be 5 HP and transfer pump is 2 HP.						
	Total pumping horsepower	21	hp				
	Building power draw	15	kW				
	Total power draw	30.75	kW				
	Unit cost of Power per kilowatt hour	$ 0.25	kW/hr	30.75	kW/hr		
	Total power consumption per year	269,370					
	TOTAL ANNUAL POWER COST				=	$67,343	
	Maintenance Cost						
	Carbon changeout per year	1	LS	$50,000	=	$50,000	
	Parts and supplies (10% of equipment cost)	1	LS	$20,600	=	$20,600	
	Shipping at 10%				=	$2,060	
	ESTIMATED MAINTENANCE COST					$72,660	
	Reporting						
	Annual O&M Report				=	$20,000	
	Data management				=	$20,000	
	Subtotal Annual O&M Cost				=	$301,891	
	Contingency at 20%				=	$60,378	
	TOTAL ANNUAL O&M COST					$362,000	

Cost Estimate Backup Sheets - Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Groundwater Alternative 3

		Quantity	Unit	Unit Cost		Extended Cost
No. 3	**Long Term Monitoring of Wells**					
	Number of samples	20	samples			
	Number of samplers	2	people			
	Number of 12 hour workdays	5	days			
	Sampling Project Planning (e.g., Staffing, Lab Procurement, Obtaining Equipment)					
	Project Manager	16	hr	$160	=	$2,560
	Geologist	50	hr	$110	=	$5,500
	Procurement Specialist	40	hr	$110	=	$4,400
	Field Sampling Labor					
	Mob/demob	60	hr	$110	=	$6,600
	Sampling	120	hr	$110	=	$13,200
	Travel Expense and per Diem					
	Van and car rental	5	day	$95	=	$475
	Sampling Equipment, Shipping, Consumable Supplies					
	Equipment & PPE	1	ea	$3,500	=	$3,500
	Shipping	5	day	$200	=	$1,000
	Misc	5	day	$75	=	$375
	Sampling Analysis					
	VOCs	27	ea	$80	=	$2,160
	MEE	27	ea	$120	=	$3,240
	TOC	27	ea	$30	=	$810
	Nitrate	27	ea	$25	=	$675
	Sulfate	27	ea	$25	=	$675
	Ferrous Iron	27	ea	$18	=	$486
	Chloride	27	ea	$15	=	$405
	Alkalinity	27	ea	$20	=	$540
	Metals	27	ea	$120	=	$3,240
	Data Validation					
	Assume samples validated @ 1 hr per sample					
	Samples management/validation	243	hr	$110	=	$26,730
	Sampling Report					
	Project Manager	16	hr	$160	=	$2,560
	Environmental Engineer	40	hr	$110	=	$4,400
	Geologist	40	hr	$110	=	$4,400
	Admin Clerk	16	hr	$75	=	$1,200
	TOTAL GROUNDWATER SAMPLING COST PER EVENT				**$**	**90,000**

Cost Estimate Backup Sheets - Alternative GW3
Focused Groundwater Extraction and Treatment
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Description: Individual Cost Item Backup for Groundwater Alternative 3

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

P = Present Worth

A= Annual amount

i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

A. Long Term Monitoring - year 3- 30

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	30
i =	7%
The multiplier for $(P/A)_2$ =	**12.409**
n =	2
i =	7%
The multiplier for $(P/A)_2$ =	**1.808**
Net	**10.601**

R2-0009044

Cost Estimate for Alternative GW4
In situ Treatment and Long-term Monitoring
Cidra Groundwater Contamination Site
Cidra, Puerto Rico

Item No.	Item Description	Extended Cost	
CAPITAL COSTS			
1.	In-situ Treatment	$	2,503,000
2.	PRBs	$	945,000
	Subtotal	**$**	**3,448,000**
	General Contractor Markup (profit, insurance etc) 20%	$	690,000
	Contingency (20%)	$	690,000
	TOTAL CAPITAL COSTS	**$**	**4,828,000**
OPERATION & MAINTENANCE (O&M) COSTS			
Annual O&M Costs			
3.	Long Term Monitoring (quarterly yr 1-2, annually yr 3 - 10)	$	90,000
PRESENT WORTH OF 30 YEAR COSTS (with discounting)			
	Total Capital Costs	$	4,828,000
	Reapplication of PRB in year 10, year 20, and year 30	$	873,000
	Monitoring Cost	$	1,674,000
	TOTAL PRESENT WORTH OF 30 YEAR COSTS	**$**	**7,375,000**

Notes:
1. Present worth calculation assumes 7% discount rate after inflation is considered.

Description:	Individual Cost Item Backup for Alternative GW4					
		Quantity	Unit	Unit Cost		Extended Cost
No. 1	**In-situ treatment**					
1a.	**Construction Management & Operations - General Conditions (18 months)**					
	Timeperiods are calculated in 5b below					
	Drilling and Injection time period	19	weeks			
	TOTAL CONSTRUCTION AND OPERATIONS TIME	19	weeks			
	Pre-Mobilization Work Planning and Supports					
	Project Manager	150	hr	$160	=	$24,000
	Environmental Engineer	150	hr	$110	=	$16,500
	Scientist	150	hr	$110	=	$16,500
	Admin Clerk	150	hr	$75	=	$11,250
	Meetings	6	LS	$3,000	=	$18,000
	Permit Applications					
	Project Manager	20	hr	$160	=	$3,200
	Environmental Engineer	160	hr	$110	=	$17,600
	Subcontractor Procurement					
	Assume procurement of driller, IDW, laboratory, drilling and injection subcontractors					
	Project Manager	60	hr	$160	=	$9,600
	Environmental Engineer	80	hr	$110	=	$8,800
	Geologist	80	hr	$110		$8,800
	Scientist	80	hr	$110	=	$8,800
	Procurement specialist	200	hr	$110	=	$22,000
	During Construction & Operations					
	Project Manager (10 hrs/wk)	191	hr	$160	=	$30,545
	Engineer (16 hrs/wk)	305	hr	$110	=	$33,600
	Site Superintendent (10 hrs/wk)	191	hr	$100	=	$19,091
	Site Trucks (2 per work week)	19	week	$250	=	$4,773
	Health and Safety Engineer (16 hrs/wk)	305	hr	$125	=	$38,182
	Admin Clerk (assume 4 hrs/wk)	76	hr	$75	=	$5,727
	Subcontract management (10 hrs/week)	191	hr	$75	=	$14,318
	Weekly calls	19	per	$500	=	$9,545
	Two Trailers with utilities	2	LS	$35,000	=	$70,000
	Site Security					
	Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend					
	Security guard	19	wk	$4,320	=	$82,473
	Remedial Action Reports					
	Project Manager	40	hr	$160	=	$6,400
	Environmental Engineer	160	hr	$110	=	$17,600
	Scientist	80	hr	$110	=	$8,800
	Admin Clerk	40	hr	$75	=	$3,000
	Geologist	80	hr	$110	=	$8,800
	Total for Construction Management					**$518,000**
1b.	**ISCO Amendment Injection**					
	Area of treatment zone in Saprolite	2,566	ft^2			
	Radius of Influence	7.5	ft			
	Total depth	150	ft bgs			
	Target Remediation Zone Thickness	50	ft			
	Estimated total porosity	0.25	--			
1c.	**Injection Point Installation Details**					
	Number of injection points	15	points			
	Treatment zone volume	128,300	ft^3			
	Volume pore space	32,075	ft^3			
	6-inch Mud Rotary borehole drilling	2,250	ft	$50	=	$ 112,500
	2-inch PVC screen	750	ft	$45	=	$ 33,750
	2-inch PVC casing	1,500	ft	$40	=	$ 60,000
	Well completion materials	2,250	ft	$8	=	$ 18,000
	Drill cuttings per drilled foot	1.5	gal/ft			
	Drill cuttings waste	3303	gal		=	$ -
	Barrels of waste	83	barrels	$250	=	$ 20,644
	Number of Rigs	1	rigs			
	Mob/demob	1	LS	$5,000	=	$ 5,000
	Injection points completed per day	0.33	points per day			
	Drilling contractor	45	days	$15,000	=	$ 681,818
	TOTAL FOR SAPROLITE INJECTION POINT INSTALLATION					**$ 931,713**

1d.	**Round 1 Injection Details**						
	Number of Rigs	1	rigs				
	Mob/demob	1	LS	$30,000	=	$	30,000
	Injection points completed per day	0.75	points per day				
	Injection contractor	20	days	$15,000	=	$	300,000
	SAPROLITE						
	Amendment ratio	0.41	lb amdmt/ft^3 poresp				
	Mass of amendment required	13,200	lbs	$1.46	=	$	19,272
	Mass of iron activator required	495	lbs	$4.10	=	$	2,030
	Mass of pH adjustment chemical required	15,127	lbs	$0.52	=	$	7,866
	Mass of hydrogen peroxide activator required	46,279	lbs	$0.28	=	$	12,958
	Delivery to site	1	LS	$5,000	=	$	5,000
	Round 2 Injection Details						
	Number of Rigs	1	rigs				
	Mob/demob	1	LS	$30,000	=	$	30,000
	Injection points completed per day	0.75	points per day				
	Injection contractor	20	days	$15,000	=	$	300,000
	SAPROLITE						
	Amendment ratio	0.41	lb amdmt/ft^3 poresp				
	Mass of amendment required	13,200	lbs	$1.46	=	$	19,272
	Mass of iron activator required	495	lbs	$4.10	=	$	2,030
	Mass of pH adjustment chemical required	15,127	lbs	$0.52	=	$	7,866
	Mass of hydrogen peroxide activator required	46,279	lbs	$0.28	=	$	12,958
	Delivery to site	1	LS	$5,000	=	$	5,000
	Round 3 Injection Details ***Assume half the treatment zone is treated in Phase 3***						
	Number of Rigs	1	rigs				
	Mob/demob	1	LS	$30,000	=	$	30,000
	Injection points completed per day	0.75	points per day				
	Injection contractor	10	days	$15,000	=	$	150,000
	SAPROLITE						
	Mass of amendment required	6,600	lbs	$1.46	=	$	9,636
	Mass of iron activator required	248	lbs	$4.10	=	$	1,015
	Mass of pH adjustment chemical required	7,564	lbs	$0.52	=	$	3,933
	Mass of hydrogen peroxide activator required	23,140	lbs	$0.28	=	$	6,479
	Delivery to site	1	LS	$2,500	=	$	2,500
	TOTAL FOR INJECTIONS					**$**	**957,815**
	Subtotal for ISCO					$	1,889,527
	Insurance and bond (5%)					$	95,000
	TOTAL IN-SITU TREATMENT					**$**	**2,503,000**

Description:	Individual Cost Item Backup for Alternative GW4					
		Quantity	Unit	Unit Cost		Extended Cost
No. 2	**In-situ treatment**					
2a.	**Construction Management & Operations - General Conditions**					
	Timeperiods are calculated in 5b below					
	Drilling, Fracturing and Injection time period	8	weeks			
	TOTAL CONSTRUCTION AND OPERATIONS TIME	8	weeks			
	Subcontractor Procurement					
	Assume procurement of fracturing and injection subcontractors					
	Project Manager	10	hr	$160	=	$1,600
	Environmental Engineer	60	hr	$110	=	$6,600
	Geologist	40	hr	$110		$4,400
	Scientist	0	hr	$110	=	$0
	Procurement specialist	60	hr	$110	=	$6,600
	During Construction & Operations (assume concurrent with ISCO)					
	Project Manager (4 hrs/wk)	32	hr	$160	=	$5,120
	Engineer (8 hrs/wk)	64	hr	$110	=	$7,040
	Site Superintendent (40 hrs/wk)	320	hr	$100	=	$32,000
	Site Trucks (2 per work days)	8	week	$250	=	$2,000
	Health and Safety Engineer (8 hrs/wk)	64	hr	$125	=	$8,000
	Admin Clerk (assume 4 hrs/wk)	32	hr	$75	=	$2,400
	Subcontract management (6 hrs/week)	48	hr	$75	=	$3,600
	Weekly calls	8	per	$500	=	$4,000
	Two Trailers with utilities	0	LS	$35,000	=	$0
	Site Security					
	Assume full time security guard, 12 hours during the weekday and 24 hours per day on weekend					
	Security guard	0	wk	$2,160	=	$0
	Remedial Action Reports					
	Project Manager		hr	$160	=	$0
	Environmental Engineer		hr	$110	=	$0
	Scientist		hr	$110	=	$0
	Admin Clerk		hr	$75	=	$0
	Geologist		hr	$110	=	$0
	Total for Construction Management					**$84,000**
	Additional Operations for Year 10, 20, and 30					
	Pre-Mobilization Work Plans					
	Project Manager	20	hr	$160	=	$3,200
	Environmental Engineer	60	hr	$110	=	$6,600
	Scientist	60	hr	$110	=	$6,600
	Admin Clerk	10	hr	$75	=	$750
	Permit Applications					
	Project Manager	20	hr	$160	=	$3,200
	Environmental Engineer	60	hr	$110	=	$6,600
	Total for Additional Management Operations					**$27,000**

2b.	**Hydraulic Fracturing and Amendment Injection**						
	Total depth	150	ft bgs				
	Width of PRB	250	ft				
	PRB thickness	50	ft				
	Fracture/injection radius of influence	15.0	ft				
	Number of fracture/injection points	13	points				
2c.	**Borings**						
	Number of Rigs	1	rigs				
	Borings completed per rig per day	0.60	per rig per day				
	Days to complete borings	22	days				
	Mob/demob	1	LS	$5,000	=	$	5,000
	4.25 inch hollow stem auger boring	1,950	ft	$30	=	$	58,500
	Drill cuttings per drilled foot	2.6	gal/ft				
	Drill cuttings waste	5070	gal		=	$	-
	Barrels of waste	127	barrels	$250	=	$	31,688
	TOTAL FOR BORINGS					**$**	**95,188**
2d.	**Fracture and Injection Details**						
	Number of Rigs	1	rigs				
	Mob/demob	1	LS	$45,000	=	$	45,000
	Fracture/Injection points completed per day	0.75	points per day				
	Fracture/Injection contractor	17	days	$27,600	=	$	469,200
	TOTAL FOR FRACTURE AND INJECTION					**$**	**514,200**
2e.	**Amendment Details**						
	Treatment zone volume assuming horizontal emplacement	375,000	ft^3				
	Estimated total porosity	0.25	--				
	Volume pore space	93,750	ft^3				
	Assume soil bulk density	100	lb/ft^3				
	Mass of soil in treatment zone	37,500,000	lbs				
	Percentage amendment by soil mass	0.27%	lb amendment/lb soil				
	Mass of amendment required	100,000	lbs	$1.90	=	$	190,000
	Delivery to site	1	LS	$20,000	=	$	20,000
	TOTAL FOR AMENDMENTS					**$**	**210,000**
	Subtotal for Deep PRB					$	819,388
	Insurance and bond (5%)					$	41,000
	TOTAL IN-SITU TREATMENT FOR PRB (year0)					**$**	**945,000**
	TOTAL IN-SITU TREATMENT FOR PRB (each at year10,20,30)					**$**	**972,000**

Description: Individual Cost Item Backup for Alternative GW4

		Quantity	Unit	Unit Cost		Extended Cost
No. 3	**Long Term Monitoring**					
	Monitoring Wells to sample	20	wells			
	Soil Vapor Samples	0	samples			
	Number of samplers	2	people			
	Number of 12 hour workdays	5	days			
	Sampling Project Planning (e.g., Staffing, Lab Procurement, Obtaining Equipment)					
	Project Manager	16	hr	$160	=	$2,560
	Geologist	50	hr	$110	=	$5,500
	Procurement Specialist	40	hr	$110	=	$4,400
	Field Sampling Labor					
	Mob/demob	60	hr	$110	=	$6,600
	Sampling	120	hr	$110	=	$13,200
	Travel Expense and per Diem					
	Van and car rental	5	day	$95	=	$475
	Sampling Equipment, Shipping, Consumable Supplies					
	Equipment & PPE	1	ea	$3,500	=	$3,500
	Shipping	5	day	$200	=	$1,000
	Misc	5	day	$75	=	$375
	Sampling Analysis					
	VOCs (groundwater)	27	ea	$80	=	$2,160
	MEE	27	ea	$120	=	$3,240
	TOC	27	ea	$30	=	$810
	Nitrate	27	ea	$25	=	$675
	Sulfate	27	ea	$25	=	$675
	Ferrous Iron	27	ea	$18	=	$486
	Chloride	27	ea	$15	=	$405
	Alkalinity	27	ea	$20	=	$540
	Metals	27	ea	$120	=	$3,240
	Data Validation					
	Assume samples validated @ 1 hr per sample					
	Samples management/validation	243	hr	$110	=	$26,730
	Sampling Report					
	Project Manager	16	hr	$160	=	$2,560
	Environmental Engineer	40	hr	$110	=	$4,400
	Geologist	40	hr	$110	=	$4,400
	Admin Clerk	16	hr	$75	=	$1,200
	TOTAL GROUNDWATER SAMPLING COST PER EVENT					**$ 90,000**

Description: Individual Cost Item Backup for Alternative GW4

PRESENT WORTH CALCULATIONS

Assume discount rate is 7%:

This is a recurring cost every year for n years.

This is a problem of the form find (P given A, i, n) or (P/A,i,n)

P = Present Worth

A= Annual amount

i = interest rate

$$P = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

$$P/F = 1 / (1+i)^n$$

A. Long Term Monitoring - year 3- 30

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	30
i =	7%
The multiplier for $(P/A)_2$ =	**12.409**
n =	2
i =	7%
The multiplier for $(P/A)_2$ =	**1.808**
Net	**10.601**

B. Reapplication of PRB in year 10, year 20, and year 30

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	10
i =	7%
The discount factor is (P/F) =	0.5083

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	20
i =	7%
The discount factor is (P/F) =	0.2584

Multiplier is (P/A) for five years minus (P/A) for year 1)

n =	30
i =	7%
The discount factor is (P/F) =	0.1314

Appendix .
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CDM Smith

Appendix B – Calculations

Site Specific Protection of Groundwater Soil Cleanup Levels

$$Soil\ Cleanup\ Level = DAF * K_{oc} * F_{oc} * C_{GW}$$

DAF = dilution attenuation factor; EPA default value = 20

K_{oc} = organic carbon partitioning coefficient (presented in table below for each contaminant)

F_{oc} = fraction of organic carbon; calculated as the average total organic carbon in soil boring samples at Ramallo – 0.25%

C_{GW} = target groundwater concentration which are the maximum contaminant levels (MCLs) (presented in table below for each contaminant)

Contaminants of Concern	K_{oc} (L/kg)	MCLs (µg/L)
cis-1,2-Dichloroethylene	40	70
Tetrachloroethylene	95	5
Trichloroethylene	61	5
Vinyl chloride	22	2

References

EPA. 1996. Soil Screening Guidance. July. OSWER Direction No. 9355.4-23.